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BUDGET IMPACT ANALYSIS OF PORTABLE WIDE-FIELD DIGITAL IMAGING FOR SCREENING OF NEONATAL VISUAL IMPAIRMENT CAUSES IN RIO DE JANEIRO, BRAZIL

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Abstract

Objective: To estimate the budget impact of portable wide-field digital imaging incorporation on screening neonatal causes of childhood blindness and visual impairment in Rio de Janeiro, Brazil

Methods: A micro costing technique was used to perform the budget impact analysis. Direct costs of indirect binocular ophthalmoscopy and red reflex test (current scenario) and portable wide-field digital image screening comprised all babies born in Rio de Janeiro's government maternity wards. A five-year time horizon was used (2020 to 2024), with three alternative scenarios (100%, 75% and 50% coverage). Finally, uncertainty analysis was used to test the impact of different input parameter values on the outcomes of the budget impact analysis.

Results: Considering 100% coverage of maternity wards, the total budget impact between 2020 and 2024 would be of USD 3,820,706.04, ranging from USD 3,139,844.34 to USD 6,099,510.35. The additional cost would be of USD 3,124,457.28 ranging from USD 2,714,492.26 to USD 4,880,608.63. The cost per digital imaging would be USD 14.38.

Conclusion: The cost of universal digital imaging screening corresponds to less than 1% of the public health budget of the city of Rio de Janeiro. The information provided in this study may help government decision makers evaluate the feasibility of implementing this new strategy in the municipal setting. Further health economic evaluations should be performed in order to verify the affordability of the implementation of this screening strategy in the Brazilian scenario, taking into account scarce human resources.

Keywords: Costs and cost Analysis, Neonatal screening, Vision Disorders, Telemedicine

Word count: 3,377

Strengths and limitations of this study

- The present paper is a budget impact analysis aimed at reducing childhood visual impairment.
- This is the first Brazilian study that addresses the budgetary impact of portable wide-field digital imaging as a model of universal neonatal screening.
- Although this paper is focused on the Brazilian perspective, it can provide a study model for other populous countries that aim to reduce childhood visual impairment.
- Future economic studies may be necessary to consolidate digital retinography as a universal screening model.

Introduction

Worldwide, around 1 million children are blind from eye diseases (excluding refractive errors), and at least 25% of the cases could have been avoided if preventive measures, diagnosis and treatment had been implemented in a timely manner (1). In Brazil, despite the socio-economic diversity and scarcity of population data in several regions, it is estimated that 0.5/1,000 children are blind (2). Childhood visual impairment has a direct impact on child development and has socio-economic implications into adulthood. Early diagnosis and treatment of ocular diseases can prevent visual impairment, improving quality of life in affected individuals and their families (1,2).

In Rio Janeiro, as well as in other Brazilian urban centers, the main causes of childhood visual impairment are ROP, infectious diseases, optic nerve abnormalities, cataract and glaucoma (3,4).

In 2002, the red reflex test (RRT) was included among other neonatal screening strategies in the state of Rio de Janeiro (5). It can identify any opacification of eye the transparent media, but with low sensitivity (17.5%) to detect posterior diseases of the eye (6). It is performed by a pediatrician in the maternity ward using a direct ophthalmoscope before hospital discharge (2). In Brazil, 98% of live births are hospital based and babies are discharged 48h after birth (7)(8). ROP is a blinding disease that occurs in preterm infants, with the highest risk in those born at less than 32 weeks of gestational age (GA) and/or birth weight (BW) below 1,500 g. The diagnosis is by indirect binocular ophthalmoscopy (IBO) performed by a skilled ophthalmologist while the infant is still in neonatal intensive care or after discharge from care (9). Currently these screening methods are not able to cover all live births, mainly due to the lack of trained professionals (10,11). In addition to insufficient coverage, the referral networks are usually inefficient, which leads to a delay in diagnosis and treatment (12).

The portable wide-field digital imaging (WFDI) as a ROP screening method was proven to be a cost-effective strategy (13), with good accuracy in identifying clinically significant (type 2 or worse) ROP (14)(15). Several large studies demonstrated the results of universal neonatal eye screening.

Although the majority of findings were retinal hemorrhages, some babies who would not be screened routinely required further referral and treatment (16,17). Wide-field neonatal anterior and posterior eye imaging performed by a non-ophthalmologist and immediate image referral and analysis by an ophthalmologist in a tertiary center might contribute to early diagnosis and increase coverage (18).

It is important to provide an economic evaluation framework to make the best use of clinical evidence and health resources in order to support health care decision-making (19). The purpose of this study was to estimate the budget impact of portable WFDI for universal newborn screening from the perspective of the Brazilian Unified National Health System (SUS) from 2020 to 2024 in the city of Rio de Janeiro.

Materials and methods

Population

The number of newborns eligible for both RRT and IBO in government maternity wards in the city of Rio de Janeiro was estimated for 2020-2024, using the autoregressive integrated moving average (ARIMA model) based on an 11-year time live birth series (2008 to 2018) (20).

Study design

This is a budget impact analysis (BIA) based on a static model that used a cost calculator developed in an Excel® 365 (Microsoft Corp., United States) spreadsheet. Population parameters, epidemiological parameters (rate of examinations and reexaminations of preterm newborns), assumptions and costs associated to the screening models were included. BIA of the portable WFDI adoption was compared with a reference scenario based on RRT and IBO.

Maternity ward survey

Twenty-four government maternity wards, twenty-three with neonatal intensive care units, in the city of Rio de Janeiro were identified. The ROP screening program was implemented in 92% (22/24). Together, these maternities admitted almost 60% (54,000) of all live births in the city in the year 2018 (21).

Neonatal screening model

The study population was stratified into three hypothetical screening strategies: i. RRT of all newborns except those requiring ROP screening (reference scenario); ii. IBO for ROP screening (reference scenario); and iii. WFDI (alternative scenario) for both populations of newborns.

Reference scenarios: The RRT would be performed on full-term and premature newborns with no indication for ROP screening (2) executed by a pediatrician using a direct ophthalmoscope, before hospital discharge. Consumables are not needed to perform the test.

Infants born with BW ≤ 1,500 grams and/or GA < 32 weeks would be submitted to IBO by a skilled ophthalmologist. The first exam would be performed between the 4th and 6th week of life and subsequent reexams performed according to the classification of the disease until its resolution (9). For estimate purposes, the rate of ROP reexamination was based on Zin et al (22). It was assumed that preterm infants screened for ROP would not be submitted to RRT.

Alternative scenario: In the alternative screening strategy, WFDI would be performed in all newborns by two nurse technicians before hospital discharge. Imaging of preterm infants with BW ≤ 1,500 grams and/or GA < 32 weeks would follow the Brazilian ROP screening guidelines (9). Images would be sent to ophthalmologist readers, so ocular abnormalities could be identified and patients who needed proper diagnosis and treatment would be referred to a specialized eye care center (11). Preterm infants with suspected images of ROP type 2 or worse would be submitted to IBO while still under neonatal care.

For this study, the RetCam Portable® (Natus Medical Incorporated, Pleasanton, CA, USA) ("RetCamP®") was used to calculate costs. The device consists of a high-resolution camera that captures images of anterior and posterior segments of the eye. As it is a portable device, it could be shared among maternities close to each other, with transportation of the RetCamP® provided by a driver. In order to estimate the number of devices and professionals needed to cover all units, the following was considered: number of live births per maternity, babie's length of stay after birth, the distance among units and the efficiency (exams/day) of the nurse technician responsible for performing the exam. The Google maps® platform was used to calculate the distance among units as well as fuel cost (gasoline).

Cost analysis

Costs were estimated from the SUS perspective and a micro costing analysis was used to estimate strategy costs. Estimate costs were based on the Brazilian National Procedure Table published elsewhere (23), plus other official sources, when necessary. The following items were considered to perform IBO and WFDI: proximetacaine hydrochloride 0.5% eye drops, tropicamide 1% eye drops, phenylephrine 2.5% eye drops, gauze, glucose solution and ophthalmic jelly (for digital imaging), as well as a nurse and a nurse technician to assist the ophthalmologist during IBO (24). It was assumed that 20.8% of preterm babies with ROP type 2 or worse and 5% infants with non-readable images would be submitted to IBO (25).

Prices of the incorporated equipment (direct and indirect ophthalmoscope, 28-diopter Volk® lens and neonatal lid speculum) were based on Brazilian official sources (23). Costs of portable wide-field digital camera, spare parts (pedal and lens) and maintenance were based on market value provided by the manufacturer. In addition, an insurance quote was provided for the device. A 5% value of the unit price was assumed for equipment maintenance. When necessary, costs were annualized using a standard discount rate of 5% (26) with an estimated 10 year equipment lifespan.

Wage values for human resources were estimated on the amount of time each professional dedicated to his/her activities in the screening processes. It was assumed that RRT would be carried out by the pediatrician in 5 minutes. In order to reflect the ROP screening reference scenario, the ophthalmologist's workload was simulated. The estimated time spent with each patient was 20 minutes for the ophthalmologist, 5 minutes for the nurse and 30 minutes for the nurse technician (24). The ophthalmologist's training values were based on Zin et al (24) and taken into account for the professional price calculation.

The cost of human resources to perform digital imaging included training for equipment set up, imaging and equipment dismantle. It was performed in two phases in order to verify the learning curve to perform the procedure. In addition, the interpretation of images by ophthalmologists was timed and the average time spent was used to calculate the predicted ophthalmologist cost.

Budget impact model

A statistical model was used for the BIA. In this model, the new intervention unit cost was multiplied by the number of individuals, in every year from 2020 to 2024.

Three hypothetical scenarios, taking into account 100%, 75% and 50% coverage of portable WFDI were considered, calculating each budget impact. Targeting a better deal (reduced price), the purchase of all the equipment would take place in the first year, but delivery would be gradual, based on a market share of 60% on the first year and 10% on each consecutive year, until the complete coverage could be reached by 2024.

The incremental budget impact was calculated through the cost difference between the reference (IBO and RRT) and the alternative (WFDI) scenarios. In 2019 all costs were expressed USD (3.94 Reais/1 USD - mean rate from March to July 2019) (27) and the unit cost of the exam was calculated based on the number of live births in 2018. Inflationary adjustments were not introduced, in accordance to Brazilian (26) and international (28) recommendations.

Sensitivity analysis

The sensitivity analysis was achieved by scenarios (26). Two scenarios were created: the best scenario with lower limit of the parameter variation, and the worst scenario with upper limit of the parameter variation (19). To create the best scenario, the following reductions were considered: 5% for the exchange rate, 74% in human resource costs and 200% in consumables cost. In regard to the worst reference scenario, the exchange rate would increase by 5%, human resources costs by 32% and consumables costs by 85%.

Validation

Face validity was executed through an interview with two experts from the Rio de Janeiro Health Department, with over twenty years' experience in management, planning, and coordination of neonatal care, who also had extensive operational and logistics knowledge of the municipal maternity wards. An interview questionnaire was developed based on the program's feasibility, resource availability and health care units' infrastructure. The internal validity was executed by members of this study through a review of all formulas, calculations and parameters used to create the model structure.

Patient and Public Involvement

No patient involved.

Results

Number of estimated procedures

The number of procedures based on the population assessment estimate through the time horizon of 2020-2024 for each screening model is shown on Table 1. Between 2020 and 2024 it is observed a variance in the number of procedures for the IBO, the RRT and the WFDI of 2,29%, 0,34% and 0,41%, respectively.

Table 1. Estimated number of procedures for each screening model from 2020 to 2024.

Year	Red reflex test (I.C. 95%)	Indirect binocular ophthalmoscopy*	Wide-field digital imaging (I.C. 95%)
2020	60,846 (54,684 – 67,701)	2,095	62,941 (56,866 – 69,666)
2021	61,190 (54,363 – 68,873)	2,175	63,365 (56,635 – 70,896)
2022	61,010 (52,887 – 70,380)	2,132	63,142 (55,129 – 72,319)
2023	61,104 (52,230 – 71,485)	2,155	63,259 (54,506 – 73,419)
2024	61,054 (51,355 – 72,585)	2,143	63,197 (53,627 – 74,476)

* Number of examinations and reexaminations in preterm infants, born at less than 32 weeks of gestational age and/or birth weight below 1,500 g. Calculated by the difference between the wide-field digital imaging and the red reflex test.

Cost analysis

Direct costs of the screening strategies

Table 2 discloses direct costs of human resources, capital, transportation and consumables related to IBO, RRT and WFDI in the city of Rio de Janeiro, Brazil. The total cost per exam is USD 34.36, USD 0.75 and USD 14.38, respectively.

Table 2. Direct costs (US$): indirect binocular ophthalmoscopy, red reflex test and wide-field digital imaging, Rio de Janeiro City, Brazil, 2019.

Cost items	Red reflex test	Indirect binocular ophthalmoscopy	Wide-field digital imaging*
	cost per exam	cost per exam	cost per exam
Human Resources	$ 0.74	$ 30.32	$ 5.90
Capital	$ 0.01	$ 3.16	$ 7.34
Consumables	$ -	$ 0.87	$ 1.13
Transportation	$ -	$ -	$ 0.02
Total	$ 0.75	$ 34.36	$14.38*

Values in 2019 US$ (3.94 reais/1 US$)
Combined strategy (wide-field digital imaging + IBO) = $ 14.27.

Detailed costs for human resources, equipment, maintenance, insurance, consumables and fuel are shown on Table 3.

Table 3. Unitary costs (US$): indirect binocular ophthalmoscopy, red reflex test and wide-field digital imaging, Rio de Janeiro City, Brazil, 2019.

	Indirect binocular ophthalmoscopy		Red reflex test		Wide-field digital imaging	
Items	**Quantity**	**Unitary cost**	**Quantity**	**Unitary cost**	**Quantity**	**Unitary cost**
Human Resources*						
Physician	7	$ 930.71	24****	$ 930.71	6	$ 930.71
Nurse technician	22***	$ 330.20	-	-	56	$ 330.20
Nurse	22***	$ 458.38	-	-	-	-
Driver	-	-	-	-	8	$ 468.46
Equipment	22	$ 2,348.45	24	$ 151.57	12	$110,550.00
Insurance**	-	-	-	-	12	$ 2,838.36
Equipment maintenance**	22	$ 117.42	24	$ 7.58	12	$ 10,164.56
Consumables	Per exam	$ 1.00	-	-	Per exam	$ 1.13
Fuel (gasoline)		-	-	-	Per week	$ 5.60

*Unitary cost corresponds to monthly salary.
** Per year.
*** 10% of the workday would be allocated to assist the exam.
**** 5% of the workday would be allocated to perform the exam.

-Wide-field digital imaging

Imaging capture: Between the first and second phase there was a 31.7% reduction in the necessary time to perform all steps of wide field imaging (including the device setup and dismantle) and a 45% decrease in time to perform the exam (patient registration, capture and selection of images), reflecting a training learning curve. At the end of the training period, each team was able to perform an exam every 13 minutes, which translated into 10 to 13 exams during a 6-hour period. To provide screening for all live births it would be necessary to have 25 fixed teams, and three additional teams due to cover vacation and maternity leave, with a total of 56 professionals.

Image interpretation: On average, 12 images were read per hour, i.e., a total of 1,200 exams per month. Six ophthalmologists would be necessary to read all images taken from all live births every year.

Portable digital camera distribution in the city of Rio de Janeiro: To cover scenario 1 (100% coverage), scenario 2 (75% coverage) and scenario 3 (50% coverage), 12, 9 and 7 portable digital cameras would be required, respectively. Hospitals would have their own equipment and staff if there were more than 100 babies to be examined / week or the hospitals were far apart. Thus, in scenario 1; 5 units would have their own device and 2 teams of nurse technicians (totaling 10 professionals) dedicated to screening. In 19 units that share 7 devices, the number of imagers would vary from 2 to 4 (total of 40 professionals), depending on the number of births in each health center.

Budget impact of wide-field digital imaging screening

The total budget impact of the WFDI for 100% coverage of maternity wards was USD 3,820,706.04 in the 5-year horizon. Compared to the reference scenario, the incremental budget impact was of USD 3,124,457.28. The budget impact considering different levels of coverage in maternity wards and sensitivity analysis are shown on Table 4.

Table 4. Total budget impact and incremental budget impact of the wide-field digital imaging for coverage of 100%, 75% and 50% of maternities wards. Rio de Janeiro City, Brazil, 2019.

BUDGET IMPACT			
	100% coverage	**75% coverage**	**50% coverage**
Total budget impact of wide-field digital imaging			
Best scenario[1]	$3,139,844.34	$2,465,530.82	$1,804,016.19
Base case[2]	$3,820,706.04	$2,988,559.67	$2,175,596.75
Worst scenario[3]	$6,099,510.35	$4,796,774.02	$3,662,056.48
Incremental budget impact of wide-field digital imaging[4]			
Best scenario[1]	$2,714,492.26	$2,040,178.73	$1,378,664.10
Base case[2]	$3,124,457.28	$2,292,310.92	$1,479,347.99
Worst scenario[3]	$4,880,608.63	$3,577,872.30	$2,443,154.76

[1]Reductions considered: 5% of exchange rate, 74% of human resource costs and 200% of consumables costs.
[2] Base case: average of the parameters (exchange rate, human resource costs and consumables costs) variation.
[3]Increases considered: 5% of exchange rate, 32% of human resources costs and 85% of consumables costs
[4] Cost difference between the reference and the alternative scenarios.
Values in 2019 US$ (3.94 reais/1 US$)

<u>Face validity</u>

During face validity, the interviewed experts pointed out some obstacles and possibilities with WFDI adoption. They both agreed that there is a deficit in the screening coverage in government maternity wards in the city of Rio de Janeiro. It has been estimated that screening coverage for term newborns ranges from 70-80% and 70-100% for premature infants (ROP screening). Furthermore, there is a lack of trained professionals, such as ophthalmologists and pediatricians, to perform screening tests in the reference scenario. Considering the reported obstacles, there is ample room to offer a new universal screening that would provide an opportunity to increase coverage.

Discussion

To the best of our knowledge, this is the first budget impact study carried out in Brazil for the implementation of WFDI system in the public health system that also addresses a public policy proposal with the intent of reducing childhood visual impairment.

Currently, in Rio de Janeiro city, the main cause of visual impairment and blindness in children is related to neonatal factors, mainly ROP, followed by cataract, glaucoma, and intrauterine infections (4). The RRT must be performed in the maternity ward by a trained pediatrician before hospital discharge (29). No official data or published studies were found regarding screening outcomes of the RRT in Rio de Janeiro city. However, a study carried out in the northeastern region of Brazil found that just over 30% of newborns with a suspected RRT were properly referred and evaluated by an ophthalmologist (30). Unfortunately, although the RRT has been mandatory since 2002 (5) and IBO is recommended for ROP screening (24), not all ophthalmology residency programs offer ROP training and there is lack of trained ophthalmologists to cover all units in the country. Caligaris et al. found that neonatal screening is insufficient, resulting in delayed diagnosis and treatment of neonatal ocular diseases (31).

Worldwide, new strategies have emerged as an alternative for universal screening, including the use of WFDI system(18). Studies in China and India suggest that WFDI can increase access to newborn eye screening and improve accuracy in identifying eye injuries (16,18). A Brazilian study found that the WFDI is highly superior in detecting ocular abnormalities in newborns comparing to the RRT. While the WFDI detected abnormalities that would require immediate referral in 6.5 % of eyes, the RRT identified irregularities only in 1.7%, representing an overall sensitivity of less than 1% (32).

Implementation of universal WFDI, between 2020-2024, for all term and preterm infants born in government maternity hospitals in the city of Rio de Janeiro would imply total expenses of approximately USD 3.8 million, considering 100% coverage of maternities (scenario 1). For the same period, almost USD 1 million would be spent in the reference scenario, which represents an incremental budget impact of USD 3.1 million. The total budget impact of wide-field imaging incorporation corresponds to nearly 0.25% of the municipal and federal resources allocated in the city's public health system in 2018. In considering 50% coverage (scenario 3) the proportion would be 0.15% and for 75% (scenario 2), 0.20% (33).

In Brazil there is no budget impact or cost-effectiveness threshold for new technology incorporation process, making it difficult to interpret economic assessments for decision-making (34). Caetano R et. al (35) demonstrated that between 2012 and 2016 the main factors that determined the incorporation of new technologies in Brazil were the additional clinical benefits over technologies already available and the low financial-budgetary impact of the technology. In this context, for the purpose of comparing strategies, WFDI could be a technology to bring additional clinical benefits to the RRT.

There are some study limitations. Firstly, the accuracy of the digital camera in most studies was based on ROP screening (14)(15). Furthermore, reports of complete economic evaluation were also based on the same population (13). Even so, despite the absence of accuracy studies of universal screening, it is assumed that the accuracy of other diseases must be higher to ROP. In regard to economic evaluation studies, expanding coverage through universal screening can reduce the cost of the procedure, making the screening proposal more efficient. Secondly, costs of remote grading system that would be used in the arrange of the reading center weren´t calculated, as we considered a tertiary center where all resources were already available.

Another limitation is the scarcity of data related to the structure and coverage of the current model (RRT) of neonatal screening. In addition, there is limited data disclosure from the ROP screening network. In this study, we tried to simulate the coverage network of the reference scenario through assumptions that were discussed during the face validity process.

Face validity, despite being considered an important stage of the BIA studies (26), is not yet routinely performed in economic evaluation reports. In the present study, the specialist`s knowledge of the Rio de Janeiro neonatal government health care added value to this research.

Moreover, the portable wide-field digital camera handling was important to estimate the cost of human resources and the efficiency of the exam. Our results show an efficiency gain after the learning period, with a reduction of exam execution time of almost 50%. In addition, the technology would reduce the opportunity cost of the pediatrician and the ophthalmologist since it could be handled by a non-medical health care professional force.

It´s still not well known if the implementation of universal WFDI would be appropriate worldwide. The majority of ocular abnormalities found in universal screening studies are transitory and will not necessarily compromise visual development (16). However, the Brazilian health system has some peculiarities that may justify the implementation of universal WFDI in the country. First, the majority of deliveries are in hospital units (7) and as a routine the child remains at least 48 hours in the maternity ward before the hospital discharge (8). Second, similar to India, there is an important lack of trained professional to perform the current screening methods making impossible to cover all live births (16). Third, t referral networks are usually inefficient, leading to a delay in diagnosis and treatment (12). Considering the Brazilian scenario, the universal WFDI could be a solution to improve the quality and the efficiency of neonatal screening, especially because of a reading center based on a tertiary hospital may facilitate referral and consequently treatment of blinding eye diseases.

Conclusion

The results provided by our study can help healthcare managers assess the feasibility of incorporating WFDI in government maternity hospitals in Rio de Janeiro. Less than 1% of the resources allocated to the city's public healthcare system could be invested over a five-year period to improve identifying the causes of childhood visual impairment, thus considering it one of the highest public healthcare priorities. Furthermore, future studies should be carried out to calculate the budget impact of the implementation of WFDI in the Brazilian health system.

Ethics statement

The present study was approved by the *Fernandes Figueira Institute/Oswaldo Cruz Foundation* Research Ethics Committee. Trained professionals also provided a written informed consent.

Contributorship statement

Conceptualization, A.A.Z and M.P; methodology, L.M.A, LM.H., A.A.Z and M.P; validation, L.M.A, LM.H., A.A.Z and M.P; formal analysis, L.M.A, LM.H., A.A.Z and M.P; statistical analysis, A.C.C.C; resources, L.M.A, LM.H., A.A.Z and M.P; data curation, L.M.A, LM.H., A.A.Z and M.P; writing original draft preparation, L.M.A, LM.H., A.A.Z and M.P; writing, review and editing L.M.A, LM.H., A.A.Z, and M.P; supervision, A.A.Z and M.P.; project administration, A.A.Z and M.P.

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Competing Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Data sharing

No additional data available

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Reporting checklist for economic evaluation of health interventions.

Based on the CHEERS guidelines.

		Reporting Item	Page Number
Title			
	#1	Identify the study as an economic evaluation or use more specific terms such as "cost-effectiveness analysis", and describe the interventions compared.	1
Abstract			
	#2	Provide a structured summary of objectives, perspective, setting, methods (including study design and inputs), results (including base case and uncertainty analyses), and conclusions	1
Introduction			
Background and objectives	#3	Provide an explicit statement of the broader context for the study. Present the study question and its relevance for health policy or practice decisions	3
Methods			

Target population and subgroups	#4	Describe characteristics of the base case population and subgroups analysed, including why they were chosen.	4
Setting and location	#5	State relevant aspects of the system(s) in which the decision(s) need(s) to be made.	4
Study perspective	#6	Describe the perspective of the study and relate this to the costs being evaluated.	6
Comparators	#7	Describe the interventions or strategies being compared and state why they were chosen.	5
Time horizon	#8	State the time horizon(s) over which costs and consequences are being evaluated and say why appropriate.	4
Discount rate	#9	Report the choice of discount rate(s) used for costs and outcomes and say why appropriate	6
Choice of health outcomes	#10	Describe what outcomes were used as the measure(s) of benefit in the evaluation and their relevance for the type of analysis performed	N/A
Meaurement of effectiveness	#11a	Single study-based estimates: Describe fully the design features of the single effectiveness study and why the single study was a sufficient source of clinical effectiveness data	N/A
Measurement of effectiveness	#11b	Synthesis-based estimates: Describe fully the methods used for identification of included studies and synthesis of clinical effectiveness data	N/A

Measurement and valuation of preference based outcomes	#12	If applicable, describe the population and methods used to elicit preferences for outcomes.	N/A
**Estimating resources and costs **			
	#13a	Single study-based economic evaluation: Describe approaches used to estimate resource use associated with the alternative interventions. Describe primary or secondary research methods for valuing each resource item in terms of its unit cost. Describe any adjustments made to approximate to opportunity costs	5-7
Methods			
Estimating resources and costs	#13b	Model-based economic evaluation: Describe approaches and data sources used to estimate resource use associated with model health states. Describe primary or secondary research methods for valuing each resource item in terms of its unit cost. Describe any adjustments made to approximate to opportunity costs.	N/A
Currency, price date, and conversion	#14	Report the dates of the estimated resource quantities and unit costs. Describe methods for adjusting estimated unit costs to the year of reported costs if necessary.	7

		Describe methods for converting costs into a common currency base and the exchange rate.	
Choice of model	#15	Describe and give reasons for the specific type of decision analytical model used. Providing a figure to show model structure is strongly recommended.	7-8
Assumptions	#16	Describe all structural or other assumptions underpinning the decision-analytical model.	8
Analytical methods	#17	Describe all analytical methods supporting the evaluation. This could include methods for dealing with skewed, missing, or censored data; extrapolation methods; methods for pooling data; approaches to validate or make adjustments (such as half cycle corrections) to a model; and methods for handling population heterogeneity and uncertainty.	7-8
Results			
Study parameters	#18	Report the values, ranges, references, and, if used, probability distributions for all parameters. Report reasons or sources for distributions used to represent uncertainty where appropriate. Providing a table to show the input values is strongly recommended.	8-9
Incremental costs and outcomes	#19	For each intervention, report mean values for the main categories of estimated costs and outcomes of interest, as well as mean differences between the comparator	10-11

		groups. If applicable, report incremental cost-effectiveness ratios.	
Characterising uncertainty	#20a	Single study-based economic evaluation: Describe the effects of sampling uncertainty for the estimated incremental cost and incremental effectiveness parameters, together with the impact of methodological assumptions (such as discount rate, study perspective).	11
Characterising uncertainty	#20b	Model-based economic evaluation: Describe the effects on the results of uncertainty for all input parameters, and uncertainty related to the structure of the model and assumptions.	N/A
Characterising heterogeneity	#21	If applicable, report differences in costs, outcomes, or cost effectiveness that can be explained by variations between subgroups of patients with different baseline characteristics or other observed variability in effects that are not reducible by more information.	11
Discussion			
Study findings, limitations, generalisability, and current knowledge	#22	Summarise key study findings and describe how they support the conclusions reached. Discuss limitations and the generalisability of the findings and how the findings fit with current knowledge.	12-14
Other			

Source of funding	#23	Describe how the study was funded and the role of the funder in the identification, design, conduct, and reporting of the analysis. Describe other non-monetary sources of support	15
Conflict of interest	#24	Describe any potential for conflict of interest of study contributors in accordance with journal policy. In the absence of a journal policy, we recommend authors comply with International Committee of Medical Journal Editors recommendations	15

 This checklist was completed on 21 September 2020 using https://www.goodreports.org/, a tool made by the EQUATOR Network in collaboration with Penelope.ai

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BUDGET IMPACT ANALYSIS OF PORTABLE WIDE-FIELD DIGITAL IMAGING FOR SCREENING OF NEONATAL VISUAL IMPAIRMENT CAUSES IN RIO DE JANEIRO, BRAZIL

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BUDGET IMPACT ANALYSIS OF PORTABLE WIDE-FIELD DIGITAL IMAGING FOR SCREENING OF NEONATAL VISUAL IMPAIRMENT CAUSES IN RIO DE JANEIRO, BRAZIL

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Abstract

Objective: To estimate the budget impact of portable wide-field digital imaging incorporation on screening neonatal causes of childhood blindness and visual impairment in Rio de Janeiro, Brazil

Methods: A micro costing technique was used to perform the budget impact analysis. Direct costs of indirect binocular ophthalmoscopy and red reflex test (current scenario) and portable wide-field digital image screening comprised all babies born in Rio de Janeiro's government maternity wards. A five-year time horizon was used (2020 to 2024), with three alternative scenarios (100%, 75% and 50% coverage). Finally, uncertainty analysis was used to test the impact of different input parameter values on the outcomes of the budget impact analysis.

Results: Considering 100% coverage of maternity wards, the total budget impact between 2020 and 2024 would be of USD 3,820,706.04, ranging from USD 3,139,844.34 to USD 6,099,510.35. The additional cost would be of USD 3,124,457.28 ranging from USD 2,714,492.26 to USD 4,880,608.63. The cost per digital imaging would be USD 14.38.

Conclusion: The cost of universal digital imaging screening corresponds to less than 1% of the government health budget of the city of Rio de Janeiro. The information provided in this study may help government decision makers evaluate the feasibility of implementing this new strategy in the municipal setting. Further health economic evaluations should be performed to verify the affordability of the implementation of this screening strategy in the Brazilian scenario, taking into account scarce human resources.

Keywords: Costs and cost Analysis, Neonatal screening, Vision Disorders, Telemedicine

Word count: 3,884

Strengths and limitations of this study

- The study addresses the budgetary impact of portable wide-field digital imaging as a model of universal neonatal eye screening.
- Non-medical health professionals were trained to perform imaging capture.
- Micro costing analysis was used to estimate strategy costs.
- Face validity was performed with skilled governmental health policy makers to confirm feasibility.
- Costs were estimated from the Brazilian Unified National Health System perspective.

Introduction

Worldwide, around 1 million children are blind from eye diseases (excluding refractive errors), and at least 25% of the cases could have been avoided if preventive measures, diagnosis and treatment had been implemented in a timely manner (1). In Brazil, despite the socio-economic diversity and scarcity of population data in several regions, it is estimated that 0.5/1,000 children are blind (2). Childhood visual impairment has a direct impact on child development and has socio-economic implications. In the United States, Wittenborn et al. estimated an economic burden of eye disorders in children of US$ 6 billion per year. In Peru, Dave et al. calculated a national lifetime burden of raising all visually impaired children secondary to ROP of around US$ 500 million (3,4). Early diagnosis and treatment of ocular diseases can reduce cost, prevent visual impairment and improving quality of life in affected individuals and their families (1,2,4).

The constitution of Brazil defines health as a universal right and a state responsibility and in 1988 the Brazilian Unified National Health System (SUS) was officially created. SUS is the Brazilian health system that reaches universal health coverage to every person legally living in the country (5). The governmental health system is financed by tax revenues and social contributions from all three levels of government (federal, state, and municipal) (6). Approximately 76% of Brazilian population is covered by SUS, in other words, the majority of population depend on this health care system (7).

In Rio Janeiro, as well as in other Brazilian urban centers, the main causes of childhood visual impairment are ROP, infectious diseases, optic nerve abnormalities, cataract and glaucoma (8,9). Currently, there are two different screening strategies to identify these diseases in Brazil, the red reflex test (RRT) and the indirect binocular ophthalmoscopy (IBO). In 2002, the RRT was included among other neonatal screening strategies in the state of Rio de Janeiro for all newborns (10). It can identify any opacification of eye the transparent media, but with low sensitivity (17.5%) to detect posterior diseases of the eye when compared to IBO and wild field digital imaging (11). It is performed by a pediatrician in the maternity ward using a direct ophthalmoscope before hospital discharge (2). In Brazil, 98% of live births are hospital-based and babies are discharged 48h after birth (12)(13).

ROP is a potentially blinding disease that occurs in preterm infants, with the highest risk in those born at less than 32 weeks of gestational age (GA) and/or birth weight (BW) below 1,500 g. The diagnosis is by IBO performed by a skilled ophthalmologist while the infant is still in neonatal intensive care or after discharge from care (14).

Currently these screening methods are not able to cover all live births, mainly due to the lack of trained professionals (15,16). In addition to insufficient coverage, the referral networks are usually inefficient, which leads to a delay in diagnosis and treatment (17). The portable wide-field digital imaging (WFDI) as a ROP screening method was proven, despite the high initial cost of the equipment, to be a cost-effective strategy (7,18). Also, it has a good accuracy (sensitivity over 70%) in identifying clinically significant (type 2 or worse) ROP when compared to indirect ophthalmoscopy, (19)(20).

Several large studies demonstrated the results of universal neonatal eye screening. Although the majority of findings were retinal hemorrhages, some babies who would not be screened routinely required further referral and treatment (21–24). Wide-field neonatal anterior and posterior eye imaging performed by a non-ophthalmologist and immediate image referral and analysis by an ophthalmologist in a tertiary center might contribute to early diagnosis and increase coverage (25).

It is important to provide an economic evaluation framework to make the best use of clinical evidence and health resources in order to support health care decision-making (26). The purpose of this study was to estimate the budget impact of portable WFDI for universal newborn screening from the perspective of the SUS from 2020 to 2024 in the city of Rio de Janeiro.

Materials and methods

Population

The number of newborns eligible for both RRT and IBO in government maternity wards in the city of Rio de Janeiro was estimated for 2020-2024, using the autoregressive integrated moving average (ARIMA model) based on an 11-year time live birth series (2008 to 2018) (27).

Study design

This is a budget impact analysis (BIA) based on a static model that used a cost calculator developed in an Excel® 365 (Microsoft Corp., United States) spreadsheet. A theoretical assumptive study model was created based on population parameters, epidemiological parameters (rate of examinations and reexaminations of preterm newborns), assumptions and costs associated to the screening models. BIA of the portable WFDI adoption was compared with a reference scenario based on RRT and IBO.

Maternity ward survey

Twenty-four government maternity wards, twenty-three with neonatal intensive care units, in the city of Rio de Janeiro were identified. The ROP screening program was implemented in 92% of the maternity wards (22/24). Together, these maternities admitted almost 60% (54,000) of all live births in the city in the year 2018 (28).

Neonatal screening model

The study population was stratified into three hypothetical screening strategies: i. RRT of all newborns except those requiring ROP screening (reference scenario); ii. IBO for ROP screening (reference scenario); and iii. WFDI (alternative scenario) for both populations of newborns.

Reference scenarios: The RRT would be performed on full-term and premature newborns with no indication for ROP screening (2) executed by a pediatrician using a direct ophthalmoscope, before hospital discharge. Consumables are not needed to perform the test.

Infants born with BW ≤ 1,500 grams and/or GA < 32 weeks would be submitted to IBO by a skilled ophthalmologist. The first exam would be performed between the 4th and 6th week of life and subsequent reexams performed according to the classification of the disease until its resolution (14). For estimate purposes, the rate of ROP reexamination was based on Zin et al (29). It was assumed that preterm infants screened for ROP would not be submitted to RRT.

Alternative scenario: In the alternative screening strategy, WFDI would be performed in all newborns by two nurse technicians before hospital discharge. Imaging of preterm infants with BW ≤

1,500 grams and/or GA < 32 weeks would follow the Brazilian ROP screening guidelines (14). Images would be sent to ophthalmologist readers, so ocular abnormalities could be identified and patients who needed proper diagnosis and treatment would be referred to a specialized eye care center (16). Preterm infants with non-readable images or with suspected images of ROP type 2 or worse would be submitted to IBO while still under neonatal care.

For this study, the RetCam Portable® (Natus Medical Incorporated, Pleasanton, CA, USA) ("RetCamP®") was used to calculate costs. The device consists of a high-resolution camera that captures images of anterior and posterior segments of the eye. As it is a portable device, it could be shared among maternities close to each other, with transportation of the RetCamP® provided by a driver. In order to estimate the number of devices and professionals needed to cover all units, the following was considered: number of live births per maternity, babie's length of stay after birth, distance among units and efficiency (exams/day) of the nurse technician responsible for performing the exam. Google maps® platform was used to calculate the distance among units as well as fuel cost (gasoline).

Cost analysis

Costs were estimated from the SUS perspective and a micro costing analysis was used to estimate strategy costs. Estimate costs were based on the Brazilian National Procedure Table published elsewhere (30), plus other official sources, when necessary. The following items were considered to perform IBO and WFDI: proximetacaine hydrochloride 0.5% eye drops, tropicamide 1% eye drops, phenylephrine 2.5% eye drops, gauze, glucose solution and ophthalmic jelly (for digital imaging), as well as a nurse and a nurse technician to assist the ophthalmologist during IBO (31). It was assumed that 20.8% of preterm babies with ROP type 2 or worse and 5% infants with non-readable images would be submitted to IBO (32).

Prices of the incorporated equipment (direct and indirect ophthalmoscope, 28-diopter Volk® lens and neonatal lid speculum) were based on Brazilian official sources (30). Costs of portable wide-field digital camera, spare parts (pedal and lens) and maintenance were based on market value provided by the manufacturer. In addition, an insurance quote was provided for the device. A 5% value of the unit price was assumed for equipment maintenance. When necessary, costs were annualized using a standard discount rate of 5% (33) with an estimated 10 year equipment lifespan.

Wage values for human resources were estimated on the amount of time each professional dedicated to his/her activities in the screening processes. It was assumed that RRT would be carried out by the pediatrician in 5 minutes. In order to reflect the ROP screening reference scenario, the ophthalmologist's workload was simulated. The estimated time spent with each patient was 20 minutes for the ophthalmologist, 5 minutes for the nurse and 30 minutes for the nurse technician (31). The ophthalmologist's training values were based on Zin et al (31) and taken into account for the professional price calculation.

The cost of human resources to perform digital imaging included training two neonatal nurses technicians for equipment set up, imaging and equipment dismantle. This training was performed in two phases separated by one month in order to verify the learning curve to perform the procedure. In addition, the interpretation of images by two ophthalmologists was timed and the average time spent was used to calculate the predicted ophthalmologist cost.

Budget impact model

A statistical model was used for the BIA. In this model, the new intervention unit cost was multiplied by the number of individuals, in every year from 2020 to 2024.

Three hypothetical scenarios, taking into account 100%, 75% and 50% coverage of portable WFDI were considered, calculating each budget impact. Targeting a better deal (reduced price), the purchase of all the equipment would take place in the first year, but delivery would be gradual, based on a market share of 60% on the first year and 10% on each consecutive year, until the complete coverage could be reached by 2024.

The incremental budget impact was calculated through the cost difference between the reference (IBO and RRT) and the alternative (WFDI) scenarios. In 2019 all costs were expressed USD (3.94 Reais/1 USD - mean rate from March to July 2019) (34) and the unit cost of the exam was calculated based on the number of live births in 2018. Inflationary adjustments were not introduced, in accordance to Brazilian (33) and international (35) recommendations.

Sensitivity analysis

The sensitivity analysis was achieved by scenarios (33). Two scenarios were created: the best scenario with lower limit of the parameter variation, and the worst scenario with upper limit of the parameter variation (26). To create the best scenario, the following reductions were considered: 5% for the exchange rate, 74% in human resource costs and 200% in consumables cost. In regard to the worst reference scenario, the exchange rate would increase by 5%, human resources costs by 32% and consumables costs by 85%.

Validation

Face validity was executed through an interview with two experts from the Rio de Janeiro Health Department, with over twenty years' experience in management, planning, and coordination of neonatal care, who also had extensive operational and logistics knowledge of the municipal maternity wards. An interview guide was developed to obtain information regarding the program's feasibility (practical aspects related to the implementation of the program), resource availability (personal information related to the cost of the program), and care units' infrastructure (information related to the current health care network). The internal validity was executed by members of this study through a review of all formulas, calculations and parameters used to create the model structure.

Patient and Public Involvement

No patient involved.

Results

Number of estimated procedures

The number of procedures based on the population assessment estimate through the time horizon of 2020-2024 for each screening model is shown on Table 1. Between 2020 and 2024 it is observed a variance in the number of procedures for the IBO, the RRT and the WFDI of 2,29%, 0,34% and 0,41%, respectively.

Table 1. Estimated number of procedures for each screening model from 2020 to 2024.

Year	Red reflex test (95% CI)	Indirect binocular ophthalmoscopy*	Wide-field digital imaging (95% CI)
2020	60,846 (54,684 – 67,701)	2,095	62,941 (56,866 – 69,666)
2021	61,190 (54,363 – 68,873)	2,175	63,365 (56,635 – 70,896)
2022	61,010 (52,887 – 70,380)	2,132	63,142 (55,129 – 72,319)
2023	61,104 (52,230 – 71,485)	2,155	63,259 (54,506 – 73,419)
2024	61,054 (51,355 – 72,585)	2,143	63,197 (53,627 – 74,476)

* Number of examinations and reexaminations in preterm infants, born at less than 32 weeks of gestational age and/or birth weight below 1,500 g. Calculated by the difference between the wide-field digital imaging and the red reflex test.

Cost analysis

Direct costs of the screening strategies

Table 2 discloses direct costs of human resources, capital, transportation and consumables related to IBO, RRT and WFDI in the city of Rio de Janeiro, Brazil. The total cost per exam is USD 34.36, USD 0.75 and USD 14.19, respectively.

Table 2. Direct costs (US$): indirect binocular ophthalmoscopy, red reflex test and wide-field digital imaging, Rio de Janeiro City, Brazil, 2019.

Cost items	Red reflex test	Indirect binocular ophthalmoscopy	Wide-field digital imaging
	cost per exam (US$)	cost per exam (US$)	cost per exam (US$)
Human Resources	0.74	30.32	5.85
Capital	0.01	3.16	7.19
Consumables	-	0.87	1.13
Transportation	-	-	0.02
Total	0.75	34.36	14.19*

Values in 2019 US$ (3.94 reais/1 US$)
*Combined strategy (wide-field digital imaging + IBO) = $ 14.27.

Detailed costs for human resources, equipment, maintenance, insurance, consumables and fuel are shown on Table 3.

Table 3. Unitary costs (US$): indirect binocular ophthalmoscopy, red reflex test and wide-field digital imaging, Rio de Janeiro City, Brazil, 2019.

	Indirect binocular ophthalmoscopy		Red reflex test		Wide-field digital imaging	
Items	**Quantity**	**Unitary cost (US$)**	**Quantity**	**Unitary cost (US$)**	**Quantity**	**Unitary cost (US$)**
Human Resources*						
Physician	7	930.71	24****	930.71	6	930.71
Nurse technician	22***	330.20	-	-	56	330.20
Nurse	22***	458.38	-	-	-	-
Driver	-	-	-	-	8	468.46
Equipment	22	2,348.45	24	151.57	12	110,550.00
Insurance**	-	-	-	-	12	2,838.36
Equipment maintenance**	22	117.42	24	7.58	12	10,164.56
Consumables	Per exam	1.00	-	-	Per exam	1.13
Fuel (gasoline)		-	-	-	Per week	5.60

*Unitary cost corresponds to monthly salary.
** Per year.
*** 10% of the workday would be allocated to assist the exam.
**** 5% of the workday would be allocated to perform the exam.

<u>-Cost and efficiency of Wide-field digital imaging</u>

Imaging capture and training: Between the first and second phase of the neonatal nurse technician training there was a 31.7% reduction in the necessary time to perform all steps of wide field imaging (including the device setup and dismantle) and a 45% decrease in time to perform the exam (patient registration, capture and selection of images), reflecting a training learning curve. At the end of the training period, each team was able to perform an exam every 13 minutes, which translated into 10 to 13 exams during a 6-hour period. To provide screening for all live births it would be necessary to have 25 fixed teams, and three additional teams due to cover vacation and maternity leave, with a total of 56 professionals.

Image interpretation: On average, 12 images were read per hour, i.e., a total of 1,200 exams per month. Six ophthalmologists would be necessary to read all images taken from all live births every year.

Portable digital camera distribution in the city of Rio de Janeiro: To cover scenario 1 (100% coverage), scenario 2 (75% coverage) and scenario 3 (50% coverage), 12, 9 and 7 portable digital cameras would be required, respectively. Hospitals would have their own equipment and staff if there were more than 100 babies to be examined / week or the hospitals were far apart. Thus, in scenario 1; 5 units would have their own device and 2 teams of nurse technicians (totaling 10 professionals) dedicated to screening. In 19 units that share 7 devices, the number of imagers would vary from 2 to 4 (total of 40 professionals), depending on the number of births in each health center.

Budget impact of wide-field digital imaging screening

The total budget impact of the WFDI for 100% coverage of maternity wards was USD 3,820,706.04 in the 5-year horizon. Compared to the reference scenario, the incremental budget impact was of USD 3,124,457.28. The budget impact considering different levels of coverage in maternity wards and sensitivity analysis are shown on Table 4.

Table 4. Total budget impact and incremental budget impact of the wide-field digital imaging for coverage of 100%, 75% and 50% of maternities wards. Rio de Janeiro City, Brazil, 2019.

BUDGET IMPACT			
	100% coverage	**75% coverage**	**50% coverage**
Total budget impact of wide-field digital imaging			
Best scenario[1]	$3,139,844.34	$2,465,530.82	$1,804,016.19
Base case[2]	$3,820,706.04	$2,988,559.67	$2,175,596.75
Worst scenario[3]	$6,099,510.35	$4,796,774.02	$3,662,056.48
Incremental budget impact of wide-field digital imaging[4]			
Best scenario[1]	$2,714,492.26	$2,040,178.73	$1,378,664.10
Base case[2]	$3,124,457.28	$2,292,310.92	$1,479,347.99
Worst scenario[3]	$4,880,608.63	$3,577,872.30	$2,443,154.76

[1]Reductions considered: 5% of exchange rate, 74% of human resource costs and 200% of consumables costs.
[2] Base case: average of the parameters (exchange rate, human resource costs and consumables costs) variation.
[3]Increases considered: 5% of exchange rate, 32% of human resources costs and 85% of consumables costs
[4] Cost difference between the reference and the alternative scenarios.
Values in 2019 US$ (3.94 reais/1 US$)

Face validity

During face validity, the interviewed experts pointed out some obstacles and possibilities with WFDI adoption. They both agreed that there is a deficit in the screening coverage in government maternity wards in the city of Rio de Janeiro. It has been estimated that screening coverage for term newborns ranges from 70-80% and 70-100% for premature infants (ROP screening). Furthermore, there is a lack of trained professionals, such as ophthalmologists and pediatricians, to perform screening tests in the reference scenario. Considering the reported obstacles, there is ample room to offer a new universal screening that would provide an opportunity to increase coverage.

Discussion

To the best of our knowledge, this is the first budget impact study carried out in Brazil for the implementation of WFDI system in the governmental health system that also addresses a public policy proposal to reduce childhood visual impairment.

Currently, in Rio de Janeiro city, the main cause of visual impairment and blindness in children is related to neonatal factors, mainly ROP, followed by cataract, glaucoma, and intrauterine infections (9). The RRT must be performed in the maternity ward by a trained pediatrician before hospital discharge (36). No official data or published studies were found regarding screening outcomes of the RRT in Rio de Janeiro city. However, a study carried out in the northeastern region of Brazil found that just over 30% of newborns with a suspected RRT were properly referred and evaluated by an ophthalmologist (37). Unfortunately, although the RRT has been mandatory since 2002 (10) and IBO is recommended for ROP screening (31), not all ophthalmology residency programs offer ROP training and there is lack of trained ophthalmologists to cover all units in the country. Caligaris et al. found that neonatal screening is insufficient, resulting in delayed diagnosis and treatment of neonatal ocular diseases (38).

Worldwide, new strategies have emerged as an alternative for universal screening, including the use of WFDI system(25). Studies in China and India suggest that WFDI can increase access to newborn eye screening and improve accuracy in identifying eye injuries (21,25). A Brazilian study found that the WFDI is highly superior in detecting ocular abnormalities in newborns comparing to the RRT. While the WFDI detected abnormalities that would require immediate referral in 6.5 % of eyes, the RRT identified irregularities only in 1.7%, representing an overall sensitivity of less than 1% (23).

Implementation of universal WFDI, between 2020-2024, for all term and preterm infants born in government maternity hospitals in the city of Rio de Janeiro would imply total expenses of approximately USD 3.8 million, considering 100% coverage of maternities (scenario 1). For the same period, USD 696.248 would be spent in the reference scenario, which represents an incremental budget impact of USD 3.1 million. The total budget impact of wide-field imaging incorporation corresponds to nearly 0.25% of the municipal and federal resources allocated in the city's government health system in 2018. In considering 50% coverage (scenario 3) the proportion would be 0.15% and for 75% (scenario 2), 0.20% (39).

In Brazil there is no budget impact or cost-effectiveness threshold for new technology incorporation process, making it difficult to interpret economic assessments for decision-making (40). Caetano R et. al (41) demonstrated that between 2012 and 2016 the main factors that determined the incorporation of new technologies in Brazil were the additional clinical benefits over technologies already available and the low financial-budgetary impact of the technology. In this context, for the purpose of comparing strategies, WFDI could be a technology to bring additional clinical benefits to the RRT.

There are study limitations that should be addressed. Because it is a BIA, the results might contain inherent uncertainty (36). In the study we create assumptions about the structural model elements and variates input values over the time horizon to predict the future. Therefore, it was important to create different scenarios at the sensitivity analyses to minimize the sources of uncertainty on the outcome of the study. Also, the accuracy of digital camera in most studies was based on ROP screening (19)(20) and reports of complete economic evaluation were also based on the same population (18). Even so, despite the absence of accuracy studies of universal screening, it is assumed that the accuracy of other diseases must be higher to ROP. Regarding economic evaluation studies, expanding coverage through universal screening can reduce the cost of the procedure, making the screening proposal more efficient. Besides, costs of remote grading system reading center weren´t calculated, as we considered a tertiary center where all resources were already available.

RetCamP® has particular limitations such as resolution of the images, especially when there is no clear ocular media, difficulty in capturing images of dark fundus or of extreme periphery (zone III) (42,43). Another limitation is the scarcity of data related to the structure and coverage of the current model (RRT) of neonatal screening. Moreover, there is limited data disclosure from the ROP screening network. In this study, we tried to simulate the coverage network of the reference scenario through assumptions that were discussed during the face validity process.

Face validity, despite being considered an important stage of the BIA studies (33), is not yet routinely performed in economic evaluation reports. In the present study, the specialist`s knowledge of the Rio de Janeiro neonatal government health care added value to this research.

Moreover, the portable wide-field digital camera handling was important to estimate the cost of human resources and the efficiency of the exam. Our results show an efficiency gain after the learning period, with a reduction of exam execution time of almost 50%. In addition, the technology would reduce the opportunity cost of the pediatrician and the ophthalmologist since it could be handled by non-medical health care professional force.

It´s still not well known if the implementation of universal WFDI would be appropriate worldwide. The majority of ocular abnormalities found in universal screening studies are transitory and will not necessarily compromise visual development (21). However, the Brazilian health system has some peculiarities that may justify the implementation of universal WFDI in the country. First, the majority of deliveries are in hospital units (12) and as a routine the child remains at least 48 hours in the maternity ward before the hospital discharge (13). Second, similar to India, there is an important lack of trained professional to perform the current screening methods making impossible to cover all live births (21). Third, referral networks are usually inefficient, leading to a delay in diagnosis and treatment (17). Considering the Brazilian scenario, the universal WFDI could be a solution to improve the quality and the efficiency of neonatal screening, especially because of a reading center based on a tertiary hospital may facilitate referral and consequently treatment of blinding eye diseases.

Conclusion

The results provided by our study can help healthcare managers assess the feasibility of incorporating WFDI in government maternity hospitals in Rio de Janeiro. Less than 1% of the resources allocated to the city's government healthcare system could be invested over a five-year period to improve identifying the causes of childhood visual impairment, thus considering it one of the highest governmental healthcare priorities. Furthermore, future studies should be carried out to calculate the budget impact of the implementation of WFDI in the Brazilian health system.

Ethics statement

The present study was approved by the *Fernandes Figueira Institute/Oswaldo Cruz Foundation* Research Ethics Committee (ID: 06814819.2.0000.5269).

Contributorship statement

Conceptualization, A.A.Z and M.P; methodology, L.M.H, LM.N, Z.F.M.V, A.A.Z and M.P; validation, L.M.H, LM.N, A.A.Z and M.P; formal analysis, L.M.H, LM.N, A.A.Z and M.P; statistical analysis, A.C.C.C; resources, L.M.H, LM.N, A.A.Z and M.P; data curation, L.M.H, LM.N, A.A.Z and M.P; writing original draft preparation, L.M.H, LM.N, Z.F.M.V, A.A.Z and M.P; writing, review and editing L.M.H, LM.N, Z.F.M.V, A.A.Z, and M.P; supervision, Z.F.M.V, A.A.Z and M.P.; project administration, Z.F.M.V, A.A.Z and M.P.

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Competing Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Data sharing

No additional data available

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Reporting checklist for economic evaluation of health interventions.

Based on the CHEERS guidelines.

		Reporting Item	Page Number
Title			
	#1	Identify the study as an economic evaluation or use more specific terms such as "cost-effectiveness analysis", and describe the interventions compared.	1
Abstract			
	#2	Provide a structured summary of objectives, perspective, setting, methods (including study design and inputs), results (including base case and uncertainty analyses), and conclusions	1
Introduction			
Background and objectives	#3	Provide an explicit statement of the broader context for the study. Present the study question and its relevance for health policy or practice decisions	3
Methods			

Target population and subgroups	#4	Describe characteristics of the base case population and subgroups analysed, including why they were chosen.	4
Setting and location	#5	State relevant aspects of the system(s) in which the decision(s) need(s) to be made.	4
Study perspective	#6	Describe the perspective of the study and relate this to the costs being evaluated.	6
Comparators	#7	Describe the interventions or strategies being compared and state why they were chosen.	5
Time horizon	#8	State the time horizon(s) over which costs and consequences are being evaluated and say why appropriate.	4
Discount rate	#9	Report the choice of discount rate(s) used for costs and outcomes and say why appropriate	6
Choice of health outcomes	#10	Describe what outcomes were used as the measure(s) of benefit in the evaluation and their relevance for the type of analysis performed	N/A
Meaurement of effectiveness	#11a	Single study-based estimates: Describe fully the design features of the single effectiveness study and why the single study was a sufficient source of clinical effectiveness data	N/A
Measurement of effectiveness	#11b	Synthesis-based estimates: Describe fully the methods used for identification of included studies and synthesis of clinical effectiveness data	N/A

Measurement and valuation of preference based outcomes	#12	If applicable, describe the population and methods used to elicit preferences for outcomes.	N/A
**Estimating resources and costs **			
	#13a	Single study-based economic evaluation: Describe approaches used to estimate resource use associated with the alternative interventions. Describe primary or secondary research methods for valuing each resource item in terms of its unit cost. Describe any adjustments made to approximate to opportunity costs	5-7
Methods			
Estimating resources and costs	#13b	Model-based economic evaluation: Describe approaches and data sources used to estimate resource use associated with model health states. Describe primary or secondary research methods for valuing each resource item in terms of its unit cost. Describe any adjustments made to approximate to opportunity costs.	N/A
Currency, price date, and conversion	#14	Report the dates of the estimated resource quantities and unit costs. Describe methods for adjusting estimated unit costs to the year of reported costs if necessary.	7

		Describe methods for converting costs into a common currency base and the exchange rate.	
Choice of model	#15	Describe and give reasons for the specific type of decision analytical model used. Providing a figure to show model structure is strongly recommended.	7-8
Assumptions	#16	Describe all structural or other assumptions underpinning the decision-analytical model.	8
Analytical methods	#17	Describe all analytical methods supporting the evaluation. This could include methods for dealing with skewed, missing, or censored data; extrapolation methods; methods for pooling data; approaches to validate or make adjustments (such as half cycle corrections) to a model; and methods for handling population heterogeneity and uncertainty.	7-8
Results			
Study parameters	#18	Report the values, ranges, references, and, if used, probability distributions for all parameters. Report reasons or sources for distributions used to represent uncertainty where appropriate. Providing a table to show the input values is strongly recommended.	8-9
Incremental costs and outcomes	#19	For each intervention, report mean values for the main categories of estimated costs and outcomes of interest, as well as mean differences between the comparator	10-11

		groups. If applicable, report incremental cost-effectiveness ratios.	
Characterising uncertainty	#20a	Single study-based economic evaluation: Describe the effects of sampling uncertainty for the estimated incremental cost and incremental effectiveness parameters, together with the impact of methodological assumptions (such as discount rate, study perspective).	11
Characterising uncertainty	#20b	Model-based economic evaluation: Describe the effects on the results of uncertainty for all input parameters, and uncertainty related to the structure of the model and assumptions.	N/A
Characterising heterogeneity	#21	If applicable, report differences in costs, outcomes, or cost effectiveness that can be explained by variations between subgroups of patients with different baseline characteristics or other observed variability in effects that are not reducible by more information.	11
Discussion			
Study findings, limitations, generalisability, and current knowledge	#22	Summarise key study findings and describe how they support the conclusions reached. Discuss limitations and the generalisability of the findings and how the findings fit with current knowledge.	12-14
Other			

Source of funding	#23	Describe how the study was funded and the role of the funder in the identification, design, conduct, and reporting of the analysis. Describe other non-monetary sources of support	15
Conflict of interest	#24	Describe any potential for conflict of interest of study contributors in accordance with journal policy. In the absence of a journal policy, we recommend authors comply with International Committee of Medical Journal Editors recommendations	15

 This checklist was completed on 21 September 2020 using https://www.goodreports.org/, a tool made by the EQUATOR Network in collaboration with Penelope.ai

BMJ Open

BUDGET IMPACT ANALYSIS OF PORTABLE WIDE-FIELD DIGITAL IMAGING FOR SCREENING OF NEONATAL VISUAL IMPAIRMENT CAUSES IN RIO DE JANEIRO, BRAZIL

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Primary Subject Heading:	Health economics
Secondary Subject Heading:	Ophthalmology, Paediatrics, Public health
Keywords:	HEALTH ECONOMICS, OPHTHALMOLOGY, NEONATOLOGY

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BUDGET IMPACT ANALYSIS OF PORTABLE WIDE-FIELD DIGITAL IMAGING FOR SCREENING OF NEONATAL VISUAL IMPAIRMENT CAUSES IN RIO DE JANEIRO, BRAZIL

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Abstract

Objective: To estimate the budget impact of portable wide-field digital imaging incorporation on screening neonatal causes of childhood blindness and visual impairment in Rio de Janeiro, Brazil.

Design: Budget impact analysis.

Settings: Rio de Janeiro, Brazil.

Participants: N/A.

Primary and secondary outcome measures: The primary outcome was the direct costs of indirect binocular ophthalmoscopy, red reflex test and portable wide-field digital image screening comprised all babies born in Rio de Janeiro's government maternity wards. The secondary outcome was the budget impact analysis of implementing the portable wide-field digital image screening in Rio de Janeiro, Brazil.

Results: Considering 100% coverage of maternity wards, the total budget impact between 2020 and 2024 would be of USD 3,820,706.04, ranging from USD 3,139,844.34 to USD 6,099,510.35. The additional cost would be of USD 3,124,457.28 ranging from USD 2,714,492.26 to USD 4,880,608.63.

Conclusion: The cost of universal digital imaging screening corresponds to less than 1% of the government health budget of the city of Rio de Janeiro. The information provided in this study may help government decision makers evaluate the feasibility of implementing this new strategy in the municipal setting. Further health economic evaluations should be performed to verify the affordability of the implementation of this screening strategy in the Brazilian scenario, taking into account scarce human resources.

Keywords: Costs and cost Analysis, Neonatal screening, Vision Disorders, Telemedicine

Word count: 3,884

Strengths and limitations of this study

- The study addresses the budgetary impact of portable wide-field digital imaging as a model of universal neonatal eye screening.
- Non-medical health professionals were trained to perform imaging capture.
- Face validity was performed with skilled governmental health policy makers to confirm feasibility.
- The study is a theoretical model with assumptions and literature-based premises.

Introduction

Worldwide, around 1 million children are blind from eye diseases (excluding refractive errors), and at least 25% of the cases could have been avoided if preventive measures, diagnosis and treatment had been implemented in a timely manner (1). In Brazil, despite the socio-economic diversity and scarcity of population data in several regions, it is estimated that 0.5/1,000 children are blind (2). Childhood visual impairment has a direct impact on child development and has socio-economic implications. In the United States, Wittenborn et al. estimated an economic burden of eye disorders in children of US$ 6 billion per year. In Peru, Dave et al. calculated a national lifetime burden of raising all visually impaired children secondary to ROP of around US$ 500 million (3,4). Early diagnosis and treatment of ocular diseases can reduce cost, prevent visual impairment and improving quality of life in affected individuals and their families (1,2,4).

The constitution of Brazil defines health as a universal right and a state responsibility and in 1988 the Brazilian Unified National Health System (SUS) was officially created. SUS is the Brazilian health system that reaches universal health coverage to every person legally living in the country (5). The governmental health system is financed by tax revenues and social contributions from all three levels of government (federal, state, and municipal) (6). Approximately 76% of Brazilian population is covered by SUS, in other words, the majority of population depend on this health care system (7).

In Rio Janeiro, as well as in other Brazilian urban centers, the main causes of childhood visual impairment are ROP, infectious diseases, optic nerve abnormalities, cataract and glaucoma (8,9). Currently, there are two different screening strategies to identify these diseases in Brazil, the red reflex test (RRT) and the indirect binocular ophthalmoscopy (IBO). In 2002, the RRT was included among other neonatal screening strategies in the state of Rio de Janeiro for all newborns (10). It can identify any opacification of eye the transparent media, but with low sensitivity (17.5%) to detect posterior diseases of the eye when compared to IBO and wild field digital imaging (11). It is performed by a pediatrician in the maternity ward using a direct ophthalmoscope before hospital discharge (2). In Brazil, 98% of live births are hospital-based and babies are discharged 48h after birth (12)(13).

ROP is a potentially blinding disease that occurs in preterm infants, with the highest risk in those born at less than 32 weeks of gestational age (GA) and/or birth weight (BW) below 1,500 g. The diagnosis is by IBO performed by a skilled ophthalmologist while the infant is still in neonatal intensive care or after discharge from care (14).

Currently these screening methods are not able to cover all live births, mainly due to the lack of trained professionals (15,16). In addition to insufficient coverage, the referral networks are usually inefficient, which leads to a delay in diagnosis and treatment (17). The portable wide-field digital imaging (WFDI) as a ROP screening method was proven, despite the high initial cost of the equipment, to be a cost-effective strategy (7,18). Also, it has a good accuracy (sensitivity over 70%) in identifying clinically significant (type 2 or worse) ROP when compared to indirect ophthalmoscopy, (19)(20).

Several large studies demonstrated the results of universal neonatal eye screening. Although the majority of findings were retinal hemorrhages, some babies who would not be screened routinely required further referral and treatment (21–24). Wide-field neonatal anterior and posterior eye imaging performed by a non-ophthalmologist and immediate image referral and analysis by an ophthalmologist in a tertiary center might contribute to early diagnosis and increase coverage (25).

It is important to provide an economic evaluation framework to make the best use of clinical evidence and health resources in order to support health care decision-making (26). The purpose of this study was to estimate the budget impact of portable WFDI for universal newborn screening from the perspective of the SUS from 2020 to 2024 in the city of Rio de Janeiro.

Materials and methods

Population

The number of newborns eligible for both RRT and IBO in government maternity wards in the city of Rio de Janeiro was estimated for 2020-2024, using the autoregressive integrated moving average (ARIMA model) based on an 11-year time live birth series (2008 to 2018) (27).

Study design

This is a budget impact analysis (BIA) based on a static model that used a cost calculator developed in an Excel® 365 (Microsoft Corp., United States) spreadsheet. A theoretical assumptive study model was created based on population parameters, epidemiological parameters (rate of examinations and reexaminations of preterm newborns), assumptions and costs associated to the screening models. BIA of the portable WFDI adoption was compared with a reference scenario based on RRT and IBO.

Maternity ward survey

Twenty-four government maternity wards, twenty-three with neonatal intensive care units, in the city of Rio de Janeiro were identified. The ROP screening program was implemented in 92% of the maternity wards (22/24). Together, these maternities admitted almost 60% (54,000) of all live births in the city in the year 2018 (28).

Neonatal screening model

The study population was stratified into three hypothetical screening strategies: i. RRT of all newborns except those requiring ROP screening (reference scenario); ii. IBO for ROP screening (reference scenario); and iii. WFDI (alternative scenario) for both populations of newborns.

Reference scenarios: The RRT would be performed on full-term and premature newborns with no indication for ROP screening (2) executed by a pediatrician using a direct ophthalmoscope, before hospital discharge. Consumables are not needed to perform the test.

Infants born with BW ≤ 1,500 grams and/or GA < 32 weeks would be submitted to IBO by a skilled ophthalmologist. The first exam would be performed between the 4th and 6th week of life and subsequent reexams performed according to the classification of the disease until its resolution (14). For estimate purposes, the rate of ROP reexamination was based on Zin et al (29). It was assumed that preterm infants screened for ROP would not be submitted to RRT.

Alternative scenario: In the alternative screening strategy, WFDI would be performed in all newborns by two nurse technicians before hospital discharge. Imaging of preterm infants with BW ≤

1,500 grams and/or GA < 32 weeks would follow the Brazilian ROP screening guidelines (14). Images would be sent to ophthalmologist readers, so ocular abnormalities could be identified and patients who needed proper diagnosis and treatment would be referred to a specialized eye care center (16). Preterm infants with non-readable images or with suspected images of ROP type 2 or worse would be submitted to IBO while still under neonatal care.

For this study, the RetCam Portable® (Natus Medical Incorporated, Pleasanton, CA, USA) ("RetCamP®") was used to calculate costs. The device consists of a high-resolution camera that captures images of anterior and posterior segments of the eye. As it is a portable device, it could be shared among maternities close to each other, with transportation of the RetCamP® provided by a driver. In order to estimate the number of devices and professionals needed to cover all units, the following was considered: number of live births per maternity, babie's length of stay after birth, distance among units and efficiency (exams/day) of the nurse technician responsible for performing the exam. Google maps® platform was used to calculate the distance among units as well as fuel cost (gasoline).

Cost analysis

Costs were estimated from the SUS perspective and a micro costing analysis was used to estimate strategy costs. Estimate costs were based on the Brazilian National Procedure Table published elsewhere (30), plus other official sources, when necessary. The following items were considered to perform IBO and WFDI: proximetacaine hydrochloride 0.5% eye drops, tropicamide 1% eye drops, phenylephrine 2.5% eye drops, gauze, glucose solution and ophthalmic jelly (for digital imaging), as well as a nurse and a nurse technician to assist the ophthalmologist during IBO (31). It was assumed that 20.8% of preterm babies with ROP type 2 or worse and 5% infants with non-readable images would be submitted to IBO (32).

Prices of the incorporated equipment (direct and indirect ophthalmoscope, 28-diopter Volk® lens and neonatal lid speculum) were based on Brazilian official sources (30). Costs of portable wide-field digital camera, spare parts (pedal and lens) and maintenance were based on market value provided by the manufacturer. In addition, an insurance quote was provided for the device. A 5% value of the unit price was assumed for equipment maintenance. When necessary, costs were annualized using a standard discount rate of 5% (33) with an estimated 10 year equipment lifespan.

Wage values for human resources were estimated on the amount of time each professional dedicated to his/her activities in the screening processes. It was assumed that RRT would be carried out by the pediatrician in 5 minutes. In order to reflect the ROP screening reference scenario, the ophthalmologist's workload was simulated. The estimated time spent with each patient was 20 minutes for the ophthalmologist, 5 minutes for the nurse and 30 minutes for the nurse technician (31). The ophthalmologist's training values were based on Zin et al (31) and taken into account for the professional price calculation.

The cost of human resources to perform digital imaging included training two neonatal nurses technicians for equipment set up, imaging and equipment dismantle. This training was performed in two phases separated by one month in order to verify the learning curve to perform the procedure. In addition, the interpretation of images by two ophthalmologists was timed and the average time spent was used to calculate the predicted ophthalmologist cost.

<u>Budget impact model</u>

A statistical model was used for the BIA. In this model, the new intervention unit cost was multiplied by the number of individuals, in every year from 2020 to 2024.

Three hypothetical scenarios, taking into account 100%, 75% and 50% coverage of portable WFDI were considered, calculating each budget impact. Targeting a better deal (reduced price), the purchase of all the equipment would take place in the first year, but delivery would be gradual, based on a market share of 60% on the first year and 10% on each consecutive year, until the complete coverage could be reached by 2024.

The incremental budget impact was calculated through the cost difference between the reference (IBO and RRT) and the alternative (WFDI) scenarios. In 2019 all costs were expressed USD (3.94 Reais/1 USD - mean rate from March to July 2019) (34) and the unit cost of the exam was calculated based on the number of live births in 2018. Inflationary adjustments were not introduced, in accordance to Brazilian (33) and international (35) recommendations.

Sensitivity analysis

The sensitivity analysis was achieved by scenarios (33). Two scenarios were created: the best scenario with lower limit of the parameter variation, and the worst scenario with upper limit of the parameter variation (26). To create the best scenario, the following reductions were considered: 5% for the exchange rate, 74% in human resource costs and 200% in consumables cost. In regard to the worst reference scenario, the exchange rate would increase by 5%, human resources costs by 32% and consumables costs by 85%.

Validation

Face validity was executed through an interview with two experts from the Rio de Janeiro Health Department, with over twenty years' experience in management, planning, and coordination of neonatal care, who also had extensive operational and logistics knowledge of the municipal maternity wards. An interview guide was developed to obtain information regarding the program's feasibility (practical aspects related to the implementation of the program), resource availability (personal information related to the cost of the program), and care units' infrastructure (information related to the current health care network). The internal validity was executed by members of this study through a review of all formulas, calculations and parameters used to create the model structure.

Patient and Public Involvement

No patient involved.

Results

Number of estimated procedures

The number of procedures based on the population assessment estimate through the time horizon of 2020-2024 for each screening model is shown on Table 1. Between 2020 and 2024 it is observed a variance in the number of procedures for the IBO, the RRT and the WFDI of 2,29%, 0,34% and 0,41%, respectively.

Table 1. Estimated number of procedures for each screening model from 2020 to 2024.

Year	Red reflex test (95% CI)	Indirect binocular ophthalmoscopy*	Wide-field digital imaging (95% CI)
2020	60,846 (54,684 – 67,701)	2,095	62,941 (56,866 – 69,666)
2021	61,190 (54,363 – 68,873)	2,175	63,365 (56,635 – 70,896)
2022	61,010 (52,887 – 70,380)	2,132	63,142 (55,129 – 72,319)
2023	61,104 (52,230 – 71,485)	2,155	63,259 (54,506 – 73,419)
2024	61,054 (51,355 – 72,585)	2,143	63,197 (53,627 – 74,476)

* Number of examinations and reexaminations in preterm infants, born at less than 32 weeks of gestational age and/or birth weight below 1,500 g. Calculated by the difference between the wide-field digital imaging and the red reflex test.

Cost analysis

Direct costs of the screening strategies

Table 2 discloses direct costs of human resources, capital, transportation and consumables related to IBO, RRT and WFDI in the city of Rio de Janeiro, Brazil. The total cost per exam is USD 34.36, USD 0.75 and USD 14.19, respectively.

Table 2. Direct costs (US$): indirect binocular ophthalmoscopy, red reflex test and wide-field digital imaging, Rio de Janeiro City, Brazil, 2019.

Cost items	Red reflex test	Indirect binocular ophthalmoscopy	Wide-field digital imaging
	cost per exam (US$)	cost per exam (US$)	cost per exam (US$)
Human Resources	0.74	30.32	5.85
Capital	0.01	3.16	7.19
Consumables	-	0.87	1.13
Transportation	-	-	0.02
Total	0.75	34.36	14.19*

Values in 2019 US$ (3.94 reais/1 US$)
*Combined strategy (wide-field digital imaging + IBO) = $ 14.27.

Detailed costs for human resources, equipment, maintenance, insurance, consumables and fuel are shown on Table 3.

Table 3. Unitary costs (US$): indirect binocular ophthalmoscopy, red reflex test and wide-field digital imaging, Rio de Janeiro City, Brazil, 2019.

	Indirect binocular ophthalmoscopy		Red reflex test		Wide-field digital imaging	
Items	**Quantity**	**Unitary cost (US$)**	**Quantity**	**Unitary cost (US$)**	**Quantity**	**Unitary cost (US$)**
Human Resources*						
Physician	7	930.71	24****	930.71	6	930.71
Nurse technician	22***	330.20	-	-	56	330.20
Nurse	22***	458.38	-	-	-	-
Driver	-	-	-	-	8	468.46
Equipment	22	2,348.45	24	151.57	12	110,550.00
Insurance**	-	-	-	-	12	2,838.36
Equipment maintenance**	22	117.42	24	7.58	12	10,164.56
Consumables	Per exam	1.00	-	-	Per exam	1.13
Fuel (gasoline)		-	-	-	Per week	5.60

*Unitary cost corresponds to monthly salary.
** Per year.
*** 10% of the workday would be allocated to assist the exam.
**** 5% of the workday would be allocated to perform the exam.

-Cost and efficiency of Wide-field digital imaging

Imaging capture and training: Between the first and second phase of the neonatal nurse technician training there was a 31.7% reduction in the necessary time to perform all steps of wide field imaging (including the device setup and dismantle) and a 45% decrease in time to perform the exam (patient registration, capture and selection of images), reflecting a training learning curve. At the end of the training period, each team was able to perform an exam every 13 minutes, which translated into 10 to 13 exams during a 6-hour period. To provide screening for all live births it would be necessary to have 25 fixed teams, and three additional teams due to cover vacation and maternity leave, with a total of 56 professionals.

Image interpretation: On average, 12 images were read per hour, i.e., a total of 1,200 exams per month. Six ophthalmologists would be necessary to read all images taken from all live births every year.

Portable digital camera distribution in the city of Rio de Janeiro: To cover scenario 1 (100% coverage), scenario 2 (75% coverage) and scenario 3 (50% coverage), 12, 9 and 7 portable digital cameras would be required, respectively. Hospitals would have their own equipment and staff if there were more than 100 babies to be examined / week or the hospitals were far apart. Thus, in scenario 1; 5 units would have their own device and 2 teams of nurse technicians (totaling 10 professionals) dedicated to screening. In 19 units that share 7 devices, the number of imagers would vary from 2 to 4 (total of 40 professionals), depending on the number of births in each health center.

Budget impact of wide-field digital imaging screening

The total budget impact of the WFDI for 100% coverage of maternity wards was USD 3,820,706.04 in the 5-year horizon. Compared to the reference scenario, the incremental budget impact was of USD 3,124,457.28. The budget impact considering different levels of coverage in maternity wards and sensitivity analysis are shown on Table 4.

Table 4. Total budget impact and incremental budget impact of the wide-field digital imaging for coverage of 100%, 75% and 50% of maternities wards. Rio de Janeiro City, Brazil, 2019.

BUDGET IMPACT			
	100% coverage	**75% coverage**	**50% coverage**
Total budget impact of wide-field digital imaging			
Best scenario[1]	$3,139,844.34	$2,465,530.82	$1,804,016.19
Base case[2]	$3,820,706.04	$2,988,559.67	$2,175,596.75
Worst scenario[3]	$6,099,510.35	$4,796,774.02	$3,662,056.48
Incremental budget impact of wide-field digital imaging[4]			
Best scenario[1]	$2,714,492.26	$2,040,178.73	$1,378,664.10
Base case[2]	$3,124,457.28	$2,292,310.92	$1,479,347.99
Worst scenario[3]	$4,880,608.63	$3,577,872.30	$2,443,154.76

[1]Reductions considered: 5% of exchange rate, 74% of human resource costs and 200% of consumables costs.
[2] Base case: average of the parameters (exchange rate, human resource costs and consumables costs) variation.
[3]Increases considered: 5% of exchange rate, 32% of human resources costs and 85% of consumables costs
[4] Cost difference between the reference and the alternative scenarios.
Values in 2019 US$ (3.94 reais/1 US$)

<u>Face validity</u>

During face validity, the interviewed experts pointed out some obstacles and possibilities with WFDI adoption. They both agreed that there is a deficit in the screening coverage in government maternity wards in the city of Rio de Janeiro. It has been estimated that screening coverage for term newborns ranges from 70-80% and 70-100% for premature infants (ROP screening). Furthermore, there is a lack of trained professionals, such as ophthalmologists and pediatricians, to perform screening tests in the reference scenario. Considering the reported obstacles, there is ample room to offer a new universal screening that would provide an opportunity to increase coverage.

Discussion

To the best of our knowledge, this is the first budget impact study carried out in Brazil for the implementation of WFDI system in the governmental health system that also addresses a public policy proposal to reduce childhood visual impairment.

Currently, in Rio de Janeiro city, the main cause of visual impairment and blindness in children is related to neonatal factors, mainly ROP, followed by cataract, glaucoma, and intrauterine infections (9). The RRT must be performed in the maternity ward by a trained pediatrician before hospital discharge (36). No official data or published studies were found regarding screening outcomes of the RRT in Rio de Janeiro city. However, a study carried out in the northeastern region of Brazil found that just over 30% of newborns with a suspected RRT were properly referred and evaluated by an ophthalmologist (37). Unfortunately, although the RRT has been mandatory since 2002 (10) and IBO is recommended for ROP screening (31), not all ophthalmology residency programs offer ROP training and there is lack of trained ophthalmologists to cover all units in the country. Caligaris et al. found that neonatal screening is insufficient, resulting in delayed diagnosis and treatment of neonatal ocular diseases (38).

Worldwide, new strategies have emerged as an alternative for universal screening, including the use of WFDI system(25). Studies in China and India suggest that WFDI can increase access to newborn eye screening and improve accuracy in identifying eye injuries (21,25). A Brazilian study found that the WFDI is highly superior in detecting ocular abnormalities in newborns comparing to the RRT. While the WFDI detected abnormalities that would require immediate referral in 6.5 % of eyes, the RRT identified irregularities only in 1.7%, representing an overall sensitivity of less than 1% (23).

Implementation of universal WFDI, between 2020-2024, for all term and preterm infants born in government maternity hospitals in the city of Rio de Janeiro would imply total expenses of approximately USD 3.8 million, considering 100% coverage of maternities (scenario 1). For the same period, USD 696.248 would be spent in the reference scenario, which represents an incremental budget impact of USD 3.1 million. The total budget impact of wide-field imaging incorporation corresponds to nearly 0.25% of the municipal and federal resources allocated in the city's government health system in 2018. In considering 50% coverage (scenario 3) the proportion would be 0.15% and for 75% (scenario 2), 0.20% (39).

In Brazil there is no budget impact or cost-effectiveness threshold for new technology incorporation process, making it difficult to interpret economic assessments for decision-making (40). Caetano R et. al (41) demonstrated that between 2012 and 2016 the main factors that determined the incorporation of new technologies in Brazil were the additional clinical benefits over technologies already available and the low financial-budgetary impact of the technology. In this context, for the purpose of comparing strategies, WFDI could be a technology to bring additional clinical benefits to the RRT.

There are study limitations that should be addressed. Because it is a BIA, the results might contain inherent uncertainty (36). In the study we create assumptions about the structural model elements and variates input values over the time horizon to predict the future. Therefore, it was important to create different scenarios at the sensitivity analyses to minimize the sources of uncertainty on the outcome of the study. Also, the accuracy of digital camera in most studies was based on ROP screening (19)(20) and reports of complete economic evaluation were also based on the same population (18). Even so, despite the absence of accuracy studies of universal screening, it is assumed that the accuracy of other diseases must be higher to ROP. Regarding economic evaluation studies, expanding coverage through universal screening can reduce the cost of the procedure, making the screening proposal more efficient. Besides, costs of remote grading system reading center weren´t calculated, as we considered a tertiary center where all resources were already available.

RetCamP® has particular limitations such as resolution of the images, especially when there is no clear ocular media, difficulty in capturing images of dark fundus or of extreme periphery (zone III) (42,43). Another limitation is the scarcity of data related to the structure and coverage of the current model (RRT) of neonatal screening. Moreover, there is limited data disclosure from the ROP screening network. In this study, we tried to simulate the coverage network of the reference scenario through assumptions that were discussed during the face validity process.

Face validity, despite being considered an important stage of the BIA studies (33), is not yet routinely performed in economic evaluation reports. In the present study, the specialist`s knowledge of the Rio de Janeiro neonatal government health care added value to this research.

Moreover, the portable wide-field digital camera handling was important to estimate the cost of human resources and the efficiency of the exam. Our results show an efficiency gain after the learning period, with a reduction of exam execution time of almost 50%. In addition, the technology would reduce the opportunity cost of the pediatrician and the ophthalmologist since it could be handled by non-medical health care professional force.

It´s still not well known if the implementation of universal WFDI would be appropriate worldwide. The majority of ocular abnormalities found in universal screening studies are transitory and will not necessarily compromise visual development (21). However, the Brazilian health system has some peculiarities that may justify the implementation of universal WFDI in the country. First, the majority of deliveries are in hospital units (12) and as a routine the child remains at least 48 hours in the maternity ward before the hospital discharge (13). Second, similar to India, there is an important lack of trained professional to perform the current screening methods making impossible to cover all live births (21). Third, referral networks are usually inefficient, leading to a delay in diagnosis and treatment (17). Considering the Brazilian scenario, the universal WFDI could be a solution to improve the quality and the efficiency of neonatal screening, especially because of a reading center based on a tertiary hospital may facilitate referral and consequently treatment of blinding eye diseases.

<u>Conclusion</u>

The results provided by our study can help healthcare managers assess the feasibility of incorporating WFDI in government maternity hospitals in Rio de Janeiro. Less than 1% of the resources allocated to the city's government healthcare system could be invested over a five-year period to improve identifying the causes of childhood visual impairment, thus considering it one of the highest governmental healthcare priorities. Furthermore, future studies should be carried out to calculate the budget impact of the implementation of WFDI in the Brazilian health system.

Ethics statement

The present study was approved by the *Fernandes Figueira Institute/Oswaldo Cruz Foundation* Research Ethics Committee (ID: 06814819.2.0000.5269).

Contributorship statement

Conceptualization, A.A.Z and M.P; methodology, L.M.H, LM.N, Z.F.M.V, A.A.Z and M.P; validation, L.M.H, LM.N, A.A.Z and M.P; formal analysis, L.M.H, LM.N, A.A.Z and M.P; statistical analysis, A.C.C.C; resources, L.M.H, LM.N, A.A.Z and M.P; data curation, L.M.H, LM.N, A.A.Z and M.P; writing original draft preparation, L.M.H, LM.N, Z.F.M.V, A.A.Z and M.P; writing, review and editing L.M.H, LM.N, Z.F.M.V, A.A.Z, and M.P; supervision, Z.F.M.V, A.A.Z and M.P.; project administration, Z.F.M.V, A.A.Z and M.P.

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Competing Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Data sharing

No additional data available

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Reporting checklist for economic evaluation of health interventions.

Based on the CHEERS guidelines.

		Reporting Item	Page Number
Title			
	#1	Identify the study as an economic evaluation or use more specific terms such as "cost-effectiveness analysis", and describe the interventions compared.	1
Abstract			
	#2	Provide a structured summary of objectives, perspective, setting, methods (including study design and inputs), results (including base case and uncertainty analyses), and conclusions	1
Introduction			
Background and objectives	#3	Provide an explicit statement of the broader context for the study. Present the study question and its relevance for health policy or practice decisions	3
Methods			

Target population and subgroups	#4	Describe characteristics of the base case population and subgroups analysed, including why they were chosen.	4
Setting and location	#5	State relevant aspects of the system(s) in which the decision(s) need(s) to be made.	4
Study perspective	#6	Describe the perspective of the study and relate this to the costs being evaluated.	6
Comparators	#7	Describe the interventions or strategies being compared and state why they were chosen.	5
Time horizon	#8	State the time horizon(s) over which costs and consequences are being evaluated and say why appropriate.	4
Discount rate	#9	Report the choice of discount rate(s) used for costs and outcomes and say why appropriate	6
Choice of health outcomes	#10	Describe what outcomes were used as the measure(s) of benefit in the evaluation and their relevance for the type of analysis performed	N/A
Meaurement of effectiveness	#11a	Single study-based estimates: Describe fully the design features of the single effectiveness study and why the single study was a sufficient source of clinical effectiveness data	N/A
Measurement of effectiveness	#11b	Synthesis-based estimates: Describe fully the methods used for identification of included studies and synthesis of clinical effectiveness data	N/A

Measurement and valuation of preference based outcomes	#12	If applicable, describe the population and methods used to elicit preferences for outcomes.	N/A
**Estimating resources and costs **			
	#13a	Single study-based economic evaluation: Describe approaches used to estimate resource use associated with the alternative interventions. Describe primary or secondary research methods for valuing each resource item in terms of its unit cost. Describe any adjustments made to approximate to opportunity costs	5-7
Methods			
Estimating resources and costs	#13b	Model-based economic evaluation: Describe approaches and data sources used to estimate resource use associated with model health states. Describe primary or secondary research methods for valuing each resource item in terms of its unit cost. Describe any adjustments made to approximate to opportunity costs.	N/A
Currency, price date, and conversion	#14	Report the dates of the estimated resource quantities and unit costs. Describe methods for adjusting estimated unit costs to the year of reported costs if necessary.	7

		Describe methods for converting costs into a common currency base and the exchange rate.	
Choice of model	#15	Describe and give reasons for the specific type of decision analytical model used. Providing a figure to show model structure is strongly recommended.	7-8
Assumptions	#16	Describe all structural or other assumptions underpinning the decision-analytical model.	8
Analytical methods	#17	Describe all analytical methods supporting the evaluation. This could include methods for dealing with skewed, missing, or censored data; extrapolation methods; methods for pooling data; approaches to validate or make adjustments (such as half cycle corrections) to a model; and methods for handling population heterogeneity and uncertainty.	7-8

Results

Study parameters	#18	Report the values, ranges, references, and, if used, probability distributions for all parameters. Report reasons or sources for distributions used to represent uncertainty where appropriate. Providing a table to show the input values is strongly recommended.	8-9
Incremental costs and outcomes	#19	For each intervention, report mean values for the main categories of estimated costs and outcomes of interest, as well as mean differences between the comparator	10-11

		groups. If applicable, report incremental cost-effectiveness ratios.	
Characterising uncertainty	#20a	Single study-based economic evaluation: Describe the effects of sampling uncertainty for the estimated incremental cost and incremental effectiveness parameters, together with the impact of methodological assumptions (such as discount rate, study perspective).	11
Characterising uncertainty	#20b	Model-based economic evaluation: Describe the effects on the results of uncertainty for all input parameters, and uncertainty related to the structure of the model and assumptions.	N/A
Characterising heterogeneity	#21	If applicable, report differences in costs, outcomes, or cost effectiveness that can be explained by variations between subgroups of patients with different baseline characteristics or other observed variability in effects that are not reducible by more information.	11
Discussion			
Study findings, limitations, generalisability, and current knowledge	#22	Summarise key study findings and describe how they support the conclusions reached. Discuss limitations and the generalisability of the findings and how the findings fit with current knowledge.	12-14
Other			

Source of funding	#23	Describe how the study was funded and the role of the funder in the identification, design, conduct, and reporting of the analysis. Describe other non-monetary sources of support	15
Conflict of interest	#24	Describe any potential for conflict of interest of study contributors in accordance with journal policy. In the absence of a journal policy, we recommend authors comply with International Committee of Medical Journal Editors recommendations	15

 This checklist was completed on 21 September 2020 using https://www.goodreports.org/, a tool made by the EQUATOR Network in collaboration with Penelope.ai