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Bedside ROP screening and telemedicine interpretation integrated to a neonatal transport system: Economic aspects and return on investment analysis

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ABSTRACT

Background and aim: Peter Cerny Ambulance Service – Premature Eye Rescue Program (PCA-PERP) uses digital retinal imaging (DRI) with remote interpretation in bedside ROP screening, which has advantages over binocular indirect ophthalmoscopy (BIO) in screening of premature newborns. We aimed to demonstrate that PCA-PERP provides good value for the money and to model the cost ramifications of a similar newly launched system.
Methods: As DRI was demonstrated to have high diagnostic performance, only the costs of bedside DRI-based screening were compared to those of traditional transport and BIO-based screening (cost-minimization analysis). The total costs of investment and maintenance were analyzed with micro-costing method. A ten-year analysis time-horizon and service provider's perspective were applied.
Results: From the launch of PCA-PERP up to the end of 2014, 3722 bedside examinations were performed in the PCA covered central region of Hungary. From 2009 to 2014, PCA-PERP saved 92,248 km and 3633 staff working hours, with an annual nominal cost-savings ranging from 17,435 to 35,140 Euro. The net present value was 127,847 Euro at the end of 2014, with a payback period of 4.1 years and an internal rate of return of 20.8%. Our model presented the NPVs of different scenarios with different initial investments, annual number of transports and average transport distances.
Conclusions: PCA-PERP as bedside screening with remote interpretation, when compared to a transport-based screening with BIO, produced better cost-savings from the perspective of the service provider and provided a return on initial investment within five years after the project initiation.

1. Introduction

1.1. Screening for retinopathy of prematurity (ROP)

Retinal vessels develop relatively late during fetal development and the vascularization is completed by a gestational age of 36 to 40 weeks; the nasal retina develops earlier, and the temporal retina develops later [1,2]. Several factors, such as hypoxia, hyperoxia, variations in blood pressure, or acidosis can interrupt the normal process [2,3]. Due to the unique dynamics of retinal vascular development, ROP rarely emerges before 31 weeks of gestation and its progression stops after 44 weeks post-conception. ROP frequency essentially depends on the gestational age or birth weight: there is a 90% chance of ROP for weights below 500 to 750 g, a 78% chance between 750 g to 1000 g, and a 42% to 47% chance below 1000 or 1500 g. Its most serious forms develop in babies born below 1500 g or before 31 weeks [2,4]. Among Swedish babies with a gestational age < 32 weeks, the cumulative incidence of any ROP was 24.1% (including 8.5% of severe forms) in the screening period of the babies [5].

Most of the long-term consequences, such as retinal detachment and blindness, strabismus, refractive disorders, cataracts, glaucoma, loss of peripheral visual field and shrinkage of the eye [2,6,7], are irreversible and deteriorate the patient's health-related quality of life. Direct and indirect costs (such as costs of healthcare, productivity loss, loss of well-being, etc.) represent a substantial social economic burden in the first four decades of life [8].

Abbreviations: BIO, binocular indirect ophthalmoscopy; DRI, digital retinal imaging; km, kilometer; ROP, retinopathy of prematurity; NICU, neonatal intensive care unit; NPV, net present value; PCA, Peter Cerny Ambulance Service; PERP, Premature Eye Rescue Program.

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Recognizing and identifying the stage progression of ROP in time is essential to ensure the best possible outcomes: this is why adequate screening plays a central role in the ROP management guidelines [4,9–11]. However, these guidelines are slightly different in several ways: (i) the gestational age and/or birth weight limits that define the population to be screened; (ii) the postnatal age when the screening has to be initiated; and (iii) the follow-up interval between two screening examinations. The Hungarian Guideline [4] defines the population to be screened by <32 weeks of gestation or birth weight ≤ 1500 g; the screening initiation is at 4 weeks postnatal age but not earlier than 31 weeks post-conception, and the follow-up intervals range from one to four weeks.

The standard method of ROP screening is binocular indirect ophthalmoscopy (BIO). After instilling mydriatic eye drops to dilate pupils, the examiner visualizes the posterior pole and nasal and temporal peripheral area of the fundus. The new technology of digital retinal imaging (DRI) instrument uses a camera to take and a computer to record the images of the fundus. The retina cameras can be classified as narrow-angle or wide-angle cameras. DRI has several advantages over binocular indirect ophthalmoscopy (BIO), as DRI makes it possible: (i) for a nurse trained in retinal imaging to perform the bedside examination; (ii) for a remote ophthalmologist to interpret the images; and (iii) for images to be archived for further interpreting, documentation, or use in medical teaching, etc. Consequently, DRI with remote interpretation can decrease the need for transport (*neonatological benefit*), can decrease the workload of ophthalmologists so less ophthalmologists are able to meet the ROP screening requirements of a given population (*health system benefit*), and DRI can save images, which allows for the retrieval of images for quality control, patient follow-up, scientific analysis or even legal issues (*documentation benefit*). The guidelines referred to above [4,9–11] do not show a preference for either screening method, but the UK Guidelines acknowledge that DRI (RetCam) is useful and baby-friendly, and the USA Guidelines state that DRI has some benefit, e.g. in objective documentation. Based on a literature review, a recent joint technical report [12] concluded that telemedicine-based remote DRI did not supplant BIO, but evidence of moderate quality supported the use of the former in identifying patients with clinically significant or referral-warranted ROP [13]. It was shown [14] that DRI resulted in significantly lower stress-related heart-rate and respiratory rate responses than conventional BIO. The wide-angle cameras compared with narrow-angle cameras provide a greater view of the retina but are more expensive and less portable [15].

Retinal imaging and remote interpretation can be classified by several aspects [16] such as (i) what angle of view the camera uses (wide or narrow), (ii) who performs the examinations (a qualified nurse or an ophthalmologist), (ii) who interprets the images (ophthalmologist or pediatric ophthalmologist), (iv) what patients are covered by the screening program (all infants or ROP cases only), and (v) how many examinations are performed per patient (single or repeated).

The diagnostic performance, i.e., the sensitivity and specificity of DRI, found in some published studies are summarized in Table 1. The results show that DRI has good or even excellent diagnostic accuracy with high sensitivity, especially in those screening outputs that are used in the PCA-PERP screening program (see later).

1.2. Premature eye rescue program of the Peter Cerny Ambulance Service for Curing Sick Babies

Peter Cerny Ambulance (PCA) Service for Curing Sick Babies was founded in 1988 with the primary aim to ensure a special neonatal inter-hospital transport facility for premature or sick newborn babies and infants between referral hospitals and level III neonatal intensive care units (NICU III). PCA working as a neonatal emergency and transport service similar to a "mobile NICU III" covers the central region of Hungary (within a 120 km vicinity of Budapest) [17]. In addition, PCA performs inter-facility transport from NICUs to special examinations or interventions. Since it was launched in 1988, PCA has transported > 61.000 babies.

The *Premature Eye Rescue Program of the Peter Cerny Ambulance Service (PCA-PERP)* was established in 2008, and this program was based on the PCA's facilities, their logistic system, their highly qualified and trained staff (Neonatal Nurse Practitioners), and their skills and experiences accumulated over 25 years. Before the launch of PCA-PERP, bedside ophthalmologic screening of premature babies in the central region of Hungary could be ensured only in NICUs by local ophthalmologists. When local ophthalmologists asked for consultation, the premature baby had to be transported to a university ophthalmologic department by PCA. Moreover, some of these babies required more than one screening examination. Hence, the obvious drawbacks of this "transport-based" screening system were the significant burden on the babies with a potential risk of deterioration in cardiac, respiratory or neurologic status, and the significant burden on PCA as well, considering that the ambulance vans almost always ran "unoccupied" before and after transporting the babies.

The objectives of establishing the PCA-PERP have been to reduce the burden on these extremely vulnerable babies by decreasing their transport needs and to optimize PCA daily transport services by decreasing "empty" transport vehicle running time. The bedside retinal imaging is

Table 1
Some characteristics of studies investigating the diagnostic performance of digital retinal imaging (DRI) in ROP (ND: no data).

Ref	Number Of infants screened	Gestational age	Outcome Of ROP screening with DRI	Sensitivity	Specificity
[13]	36	Range: 23–33 weeks	Referral-warranted ROP (ROP in zone 1, plus disease or any stage 3 ROP)	100%	96%
[19]	27	Range: 28–36 weeks	Any ROP	85.71%	91.66%
[20]	64	Range: 23–32 weeks	Any ROP	81.6%–86.4%* (*ranges of the values of three image readers)	49.3–95.5%* (*ranges of the values of three image readers)
			Treatment-requiring ROP	85.0–90.0%* (*ranges of the values of three image readers)	95.3%–97.3%* (*ranges of the values of three image readers)
[21]	67	Range: 23–33 weeks	Mild or worse ROP	72.9%–93.8%	89.3%–97%
			Type 2 pre-threshold or worse ROP	71.4%–85.7%	92.8%–96.9%
			Treatment-requiring ROP	ND	93.8%–100%
[22]	51	Median: 26.9 weeks (interquartile range: 2.43 weeks)	Clinically significant ROP (that required on-site examination by an ophthalmologist)	92%	37.2%
[23]	43	Range: 23–33 weeks	Pre-threshold and threshold ROP	100%	97.5%
[24,25]	After 18 months: 97 After 36 months: 230	Range: 25–35 weeks	Referral-warranted ROP (ETROP type 2 or greater, threshold disease, any plus disease, and any stage 4 or higher disease)	After 97 infants screened: 100% After 230 infants screened: 100%	after 97 infants screened: 98.9% after 230 infants screened: 99.5%
[27]	1257	Mean: 27 weeks (standard deviation 2.2)	Referral-warranted ROP (considering both eyes)	90%	87%

performed by qualified neonatal nurse practitioners with a RetCam Shuttle (Clarity Medical Systems, Pleasanton, CA, USA) portable wide-angle retinal camera, after which a remote ophthalmologist skilled in ROP interprets the images. Referral-warranted ROP is the intended ROP type being screened [13]. Involving neonatal nurse practitioners trained and qualified both in retinal imaging examinations and in monitoring and supporting babies' life functions warrants that the image quality be excellent and the examinations be performed under safe circumstances (as if they were performed in a NICU).

Because the National Health Insurance Fund in Hungary does not pay for the cost of health investments, PCA had to bear the significant costs of a RetCam Shuttle purchase and the initial training of the staff at the time of the service launch. However, the operation of the service was assumed to result in cost-saving, mainly by decreasing ambulance van usage time.

The primary objective of our analysis was to demonstrate that investment in the operation of the PCA-PERP provides good value for the money in a 10-year time horizon by calculating the actual costs and savings in the first 6 years and modelling them for the next 4 years.

2. Methods

For many years, PCA has been financed by the National Ambulance Service with an annually determined fee that does not include costs of health investment, and this financial environment has not been changed significantly. This is the reason why all investment and potential benefit were analyzed from the PCA's perspective.

Because (i) DRI combined with remote interpretation can reasonably be assumed to have similar diagnostic performance to that of BIO; and (ii) the analysis has been performed from the service provider's (i.e., PCA's) perspective, an investment analysis has been conducted to quantify the investment indicators and to demonstrate that PCA-PERP is a good return on investment. Although the screening activity was actually initiated at the beginning of 2010, the PCA-PERP project was launched in 2009 by purchasing the RetCam Shuttle and training the staff in its use, so the 10-year time horizon of our analysis begins in 2009 and covers a period of 10 years, lasting until the end of 2018. Because at the time of analysis only the data from 2009 to 2014 (six full years) were available, the data of 2014 has been projected for the remaining years (2015–2018).

Two analysis groups have been defined: the active group ("RetCam group") in which the micro costing calculation was based on real costs incurred between 2009 and the end of 2014, and the comparator group ("Traditional Transport group") in which the micro-costing calculation was based on hypothetical data, as if the screening had been carried out in the traditional way of transporting all babies between facilities. Obviously, the difference between the cumulative costs of these groups mirrors the savings of the project.

Considering that all relevant data required for our calculation, including the number of RetCam transports and eye examinations, have been recorded since the beginning of PCA-PERP, the transport distance-based and time-based costs could easily be calculated. Cost elements used in each analysis group are listed in Table 2.

Table 3 shows the inputs used for the analyses: cost inputs (initial investment and annual overhead costs) and other inputs. In addition, some assumptions had to be made: (i) some unit costs – costs of labor, fuel – incurred in each group were the same; (ii) beyond the normal operating cost for everyday usage of the retinal camera, a service maintenance cost has been calculated for the sixth year of operation; and (iii) the annual total cost in both groups (and their differences) have been assumed to be the same from 2015 through 2018 (total costs of 2014 have been projected). The net present value (NPV) and the internal rate of return have been calculated for 2014. All costs incurred before 2014 have been adjusted with consumer price indices and all estimated costs incurred after 2014 have been discounted (with the rate of 3.7% as recommended by the *Guidelines for Health-Economic Analyses in Hungary* [18]). To express the costs in Euro, mean exchange rates have been used for each year from 2009 to 2014, and the average of these year-specific means has been used for the years after 2014. However, no overhead costs (building upkeep, salaries of emergency vehicle dispatchers and other personnel costs) have been imputed because PCA does not need to provide additional general resources for the running expenses of PCA-PERP. No direct or indirect costs saved by avoiding transport injuries of infants have been taken into account, due to the uncertainty of their estimation and the lack of clinical evidence regarding lost health capital. Based on the calculation above, the financial balance and the NPV at the end of 2014, the payback period and the ROI have been calculated. In addition, two scenarios of a newly established hypothetical ROP screening service have been modelled with different annual examination numbers and mean transport distances.

Table 2
Cost elements used for the analysis.

Cost elements	
In RetCam group	In traditional transport group
Initial investment	Costs of transporting the babies
• Tangible assets (RetCam Shuttle camera, computers) • Human capital (staff education)	• Costs of transporting patients • Staff gross salaries • Costs of consumables related to transporting the babies
PERP-specific maintenance costs	
• RetCam Shuttle maintenance (operating and large scale during the sixth year of service operation) • Maintenance training and new staff education	
Costs of the retinal camera transporting and screening examination	
• Costs of transporting the RetCam Shuttle camera • Staff gross salaries • Costs of consumables and medicines used for a screening examination	

3. Results

3.1. Savings and financial results

From the launch of the PCA-PERP project until the end of 2014, 3722 bedside screening examinations were performed in 25 hospitals in the region covered by PCA, and the retinal camera was transported to the sites 799 times. PCA-PERP saved 92,248 km in transport vehicle running distances and 3633 staff working hours for PCA between 2009 and 2014. The annual saved nominal costs were 17,435 Euro, 24,608 Euro, 21,819 Euro, 33,609 Euro and 35,140 Euro from 2009 to 2014, respectively (Table 4). Taking into account the initial investments, the financial balance of PCA-PERP broke even in the second half of 2013, after 4 years of operation. Adjusting all annual costs before 2014 with consumer prices indices and discounting all estimated annual costs after 2014, the net present value of PCA-PERP was 127,847 Euro and the internal rate of return was 20.8% in 2014 (Table 4).

3.2. A modelling comparison of a newly established bedside ROP screening service to a traditional transport-based screening system

The aim of our modelling comparison was to investigate how much cost-savings a newly established PCA-PERP-like ROP screening system can achieve with different inputs compared to a traditional transport-based screening system, assuming that the same number of infants would need to be transported for screening examinations from the same distances and assuming the new system is built onto an existing

Table 3
Inputs for the cost analyses (*Actual inputs in 2014 have been used for calculation in the period beyond 2014).

	2009	2010	2011	2012	2013	2014*
Cost inputs						
Initial investment in RetCam group: tangible assets and human capital (total, Euro)	83,809	–	–	–	–	–
PERP-specific annual maintenance costs (Euro/year)	–	1612	2020	1741	1697	1697
Unit cost of transporting (Euro/km)	–	0.9	1.0	0.9	0.9	0.9
Unit cost of labor of the whole staff (Euro/working hour)		9.6	9.3	8.9	8.7	8.3
Unit costs of consumables and medicines in RetCam group (Euro/investigation)	–	3.6	3.6	3.5	3.4	3.2
Unit costs of consumables in traditional transport group (Euro/investigation)	–	10.9	10.7	10.4	10.1	9.7
Other inputs						
Mean currency exchange rate (HUF/Euro)	280,6	275,4	279,2	289,4	296,9	308.7
Discount rate for years 2015 to 2018: 3.7%						
Large scale maintenance of RetCam: 10% of initial purchasing cost in the sixth year of operation						

neonatal transport system (i.e., no additional overhead costs need to be imputed). The inputs of PCA-PERP have been used and extrapolated for a 10-year time horizon, however the ranges of annual screening examinations (from 200 to 800) and mean inter-facility distances (5 to 50 km) have been adjusted to the service areas of the remaining medical universities in Hungary, that are smaller than the area of the PCA-PERP which covers the larger central region of the country. Two investment scenarios have been modelled: the first scenario represents the "basic investment", where – similar to PCA-PERP – the ROP screening is established by integrating it into an existing service (meaning approximately an 84,000 Euro initial investment), while the other represents a "full investment" scenario, in which all elements of the ROP screening service (including retina camera, transport vehicles, other facilities, etc.) have to be purchased and the whole staff has to be educated (meaning approximately a 135,000 Euro initial investment). Fig. 1 and Fig. 2 show the net present values of these scenarios in relation to the annual screening examination numbers and mean transport distances (discounting all costs in the future with 3.70% and applying half-cycle correction in the first year). The charts show that the more annual screening examinations are required and the larger the mean distance between the NICUs and the ophthalmology centers is the more net present value may be generated over a 10-year period. In the first scenario, the net present value of 200 examinations per year becomes positive over a 30 km mean inter-facility distance. With 800 examinations a year, the net present value turns positive at approximately 10 km and 15 km mean inter-facility distances in the basic and the full investment scenarios, respectively.

Table 4
Annual saved transport distance, working hours and costs, and indicators of return on investment. (*In 2009, the project was launched with the initial investments but there was no screening activity.)

	2009*	2010	2011	2012	2013	2014
PCA-PERP performance						
Annual number of examinations	–	710	751	741	732	784
Annual number of RetCam transports		143	151	147	163	195
Annual total vehicle usage (km)		2217	7532	6463	8682	9177
Annual total time spent with PCA-PERP (h)		469	567	538	598	675
Annual saving with PCA-PERP (comparing with "Traditional Transport")						
Annual saved running distance (km)		9166	15,259	13,198	26,884	27,741
Annual saved working hour (h)		542	709	667	847	868
Annual saved costs (Euro)		17,435	24,608	21,819	33,609	35,140
Financial balance at the end of 2014 (Euro): 40,312						
Payback period: 4.1 years						
Net present value in 2014 (Euro): 127,847						
Internal rate of return: 20.8%						

4. Discussion

ROP is a complex and significant disease specifically affecting immature infants. The long-term consequences of ROP can result in severe eye pathologies, visual impairment, or total blindness [2,6,7]. Most of these complications are irreversible, and can result in a significant burden to the patients themselves, their families and society [8]. Therefore, guidelines [4,9–11] emphasize the importance of regular screening to diagnose ROP in its early stages when the best treatment outcomes can be achieved. The DRI by using a special camera has become widely popular. DRI makes it possible to screen babies bedside, thus eliminating the need to transport them, and DRI saves and forwards retina images for remote interpretation. A number of studies have evaluated the diagnostic performance of retinal imaging and have found it to have very high sensitivity and specificity in identifying cases that require further follow-up or treatment [13,19–27].

The PCA-PERP was established to ensure the bedside ROP screening of vulnerable premature infants and to avoid having to transport them. In this program, retinal imaging is performed by qualified nurses using a RetCam Shuttle, and referral-warranted ROP was chosen as a screening target. Based on the results of several studies, the DRI was reasonably assumed to have similar diagnostic performance as the traditional BIO, so only the costs were analyzed comparing the new method of bedside DRI and the traditional transport-based screening. The analyses were performed from the service provider's (PCA's) point of view, as all costs and savings arose in PCA, and indirect and non-health system costs were not taken into account.

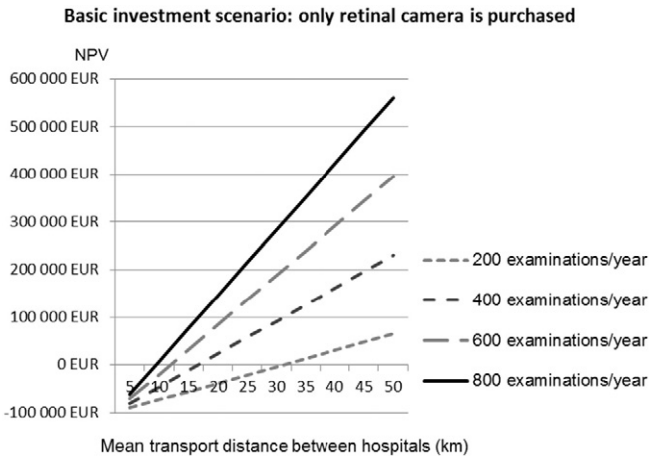

Fig. 1. Net Present Value (NPV) of a newly established ROP screening system, as a function of the expected annual number of screenings and the mean distance between the hospitals where the newborns receive care and ophthalmology center – *a basic scenario* (km: kilometer).

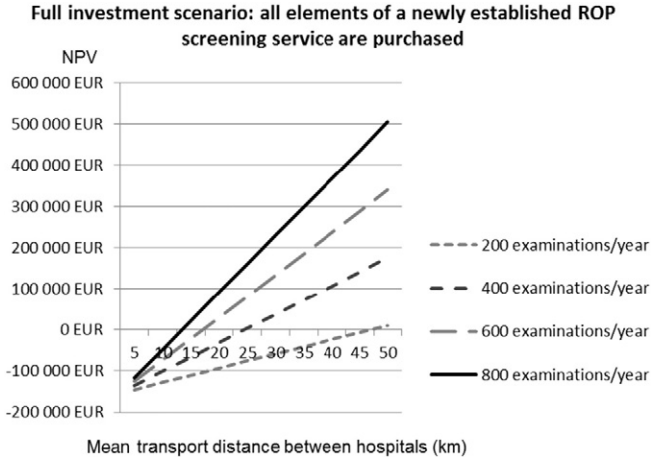

Fig. 2. Net Present Value (NPV) of a newly established ROP screening system, as a function of the annual number of screenings and the mean distance between the hospitals where the newborns receive care and ophthalmology center – *a full investment scenario* (km: kilometer).

The initial investment and maintenance costs were returned within the first half of the 10-year analysis time horizon. *The high value of internal rate of return and net present value, together with the scientific literature, supported our initial hypothesis that PCA-PERP provides good value for the money, compared to the traditional patient transport-based BIO. There is some evidence to assume that PCA-PERP can offer the same screening outcomes as BIO, whereas PCA-PERP implies lower costs, and therefore can be considered a cost-saving alternative of BIO in ROP screening. In addition, it can be assumed that the decrease in need for transporting babies has a beneficial effect on their vital stability, respiratory and cardiac status.*

However, it should be emphasized that the actual system of PCA-PERP – i.e., that it was integrated into an existing neonatal transport service – played an essential role in these favorable economic results. To model the system as a "greenfield" investment (including the cost of a reading center, transport vehicle and staff education, in addition to a digital retina camera), many more annual examinations (and/or larger distances between the facilities) are required to investigate whether the net present value of the investment turns positive.

Our analysis was subject to limitations. One of the most important is that, currently, we have no data on whether PCA-PERP can improve the screening coverage rate in the population requiring screening. However, we suppose that the bedside screening examination may involve infants whose general status makes their transport to ophthalmologic clinics impossible, which would result in delayed intervention and consequently a worse ROP and vision outcome with higher healthcare costs as well as other costs for the remainder of patients' lives. Although the scenarios of our model for a newly established screening service can provide a good basis to begin planning, more inputs (including epidemiology data) need to be taken into account to build more sophisticated scenarios.

It should be emphasized that although our analysis did not take into account indirect costs, we believe that the healthcare cost-savings from not having to transport these immature, extremely vulnerable infants is just as important as the costs the PCA-PERP can save.

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