Telemedical Evaluation and Management of Retinopathy of Prematurity Using a Fiberoptic Digital Fundus Camera

Steven D. Schwartz, MD,[1] Steven A. Harrison, MD,[1] Philip J. Ferrone, MD,[2] Michael T. Trese, MD[2]

Objective: We sought to determine whether retinopathy of prematurity (ROP) can be evaluated and managed telemedically.

Design: Multicenter noncomparative case series.

Participants: Ten patients (19 eyes) with ROP were evaluated and treated per standard of care and imaged with the RetCam 120 digital fundus camera (Massie Research Laboratories, Inc., Dublin, CA).

Intervention: Images were transmitted to a remote site for evaluation and management recommendations.

Main Outcome Measures: Telemedical evaluations and management recommendations were compared with traditional on-site standard of care evaluations and treatments.

Results: The identification of Plus disease at the remote site was accurately identified in 95% of eyes. Prethreshold, threshold, and stage 4 or 5 ROP were correctly detected in 17 of 19 (89%) eyes.

Conclusions: Results indicate ROP can be evaluated and treatment recommendations made at remote sites with telemedicine strategies. *Ophthalmology 2000;107:25–28 © 2000 by the American Academy of Ophthalmology.*

One proposed solution for many problems facing medicine in general and for the problems specifically facing retinopathy of prematurity (ROP) is the use of digital information management and the advent of telemedicine. Telemedicine is the remote evaluation and management of a patient. The advent of digital cameras that can acquire panoramic images of the neonatal fundus may have a great impact on the evaluation and management of ROP. The RetCam 120 is a fiberoptic, digital, color fundus camera that has been shown by Harrison et al (Invest Ophthalmol Vis Sci 1998;39 [Suppl]:591) to be capable of imaging all stages and many clinical features of ROP. This technology, coupled with the explosion of digital telecommunications technologies, may allow for the remote evaluation and management of ROP and thus may bring timely expertise to bear in screening and treating ROP that would otherwise be days or weeks and many health care dollars away.

Despite major advances in treatment outcomes, ROP remains a leading cause of childhood blindness in the developed world.[1,2] Treatment advances include the indirect laser delivery systems for the treatment of threshold ROP and lens-sparing vitrectomy for the treatment of certain retinal detachments (RDs).[3,4] In fact, multiple reports suggest that even the most severe posterior ROP, or zone 1 disease, can now be effectively treated in more than 80% of cases if treatment is complete and timely. Compared with 30% success rates for similar cases reported in the CRYO-ROP Study, this is a truly remarkable improvement.

Similar advances in neonatology have yielded remarkable circumstances: younger and smaller premature infants are surviving, even in community hospitals. Extremely low-birth-weight infants or "micropremies" (children born at or less than 600 g) routinely survive to be discharged from the neonatal intensive care unit.[5–8] Conservative data suggest that fewer than 50% of these children have significant comorbidity, yet a high percentage of these children have significant ROP develop.[2,3] Furthermore, neonatologists, like the rest of medicine, are discharging their patients from the hospital earlier and earlier. Thus, the ophthalmic community is confronted with more high-risk neonates to screen for ROP, both in the neonatal intensive care unit and as outpatients. Patients are of increasingly lower gestational age and birth weight and have not only a higher potential for significant ROP but also pose a significant diagnostic challenge to the examining ophthalmologist. These difficult examinations combined with ever-shrinking resources and one of the highest medical-legal liabilities in ophthalmology make the commitment necessary to efficiently evaluate, track, and treat ROP patients even more challenging.

The purpose of this investigation is to evaluate whether ROP can be evaluated and managed telemedically.

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[1] Jules Stein Eye Institute, UCLA School of Medicine, Los Angeles, California.

[2] Associated Retinal Consultants, Royal Oak, Michigan.

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Reprint requests to Steven D. Schwartz, MD, Jules Stein Eye Institute, UCLA, 100 Stein Plaza, Los Angeles, CA 90095.

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Methods

All patients at the UCLA medical center meeting ROP screening criteria undergo RetCam 120 digital imaging at each evaluation and before and after each treatment intervention as a part of the UCLA ROP & Pediatric Retinal Disease Registry. Nineteen eyes of 10 patients were evaluated and treated by the standard of care at the UCLA Medical Center and Jules Stein Eye Institute. Acquired images were coded for anonymity and electronically transmitted to Royal Oak, Michigan, for telemedical consultation by two masked specialists. Release of medical information was granted by the guardian of each patient before electronic transmission. Postconceptual age and birth weight data were included for each patient. Image transmission was accomplished by means of the internet with secure file transfer protocols (Jules Stein Eye Institute password-protected server) and duplicate transfer achieved by means of magnetic tape diskette (Zip Drive, Iomega, Roy, Utah). Each image was acquired and saved in bitmap format and transmitted unaltered and uncompressed.

Each eye was documented with an average of nine images. Each image contained 1 mb of data. A protocol for image acquisition consisting of posterior pole images followed by more peripheral images was followed. Images centered on the optic disc and macula were obtained (Figure 1). Then the superior, inferior, nasal, and temporal fundus at the 12-, 3-, 6-, and 9-o'clock meridians were imaged. Attempts were made to secure images that were sharply focused and that had balanced lighting. Also, efforts were made to image as much of the peripheral fundus as possible in the principal meridians.

Telemedical consultation results were divided into evaluations (presence or absence of ROP and Plus disease, prethreshold, threshold, stage 4, or stage 5 ROP) and into treatment recommendations (observe, further examination, laser, scleral buckle, vitrectomy). Telemedical examiners were masked to on-site diagnoses and management decisions. Results of the telemedical evaluations were transmitted back to the patient location (UCLA) and were compared with local diagnoses and treatment strategies.

Results

Nineteen eyes of 10 patients with ophthalmoscopically diagnosed ROP underwent digital fundus imaging with the RetCam 120 camera. All images were acquired by retina faculty or fellows. Patients ranged in postconceptual age from 24 to 26 weeks and in birth weight from 610 to 1041 g.

Local standard of care evaluations and management decisions were compared with remote telemedical evaluations and management recommendations. Table 1 details the comparisons. The remote experts performed telemedical consultations independently, and both were in agreement on 19 of 19 (100%) evaluation and management decisions.

The presence or absence of Plus disease was determined by both local and remote evaluation. Plus disease was accurately

Table 1. Evaluation and Management Recommendations for Retinopathy of Prematurity: On-site vs. Remote Site

	Evaluation		Management		Plus Disease	
	On-site	*Remote site*	*On-site*	*Remote site*	*On-site*	*Remote site*
Case 1						
OD	Threshold*	Prethreshold*	Laser	Observe	+	+
OS	Threshold	Prethreshold	Laser	Observe	+	+
Case 2						
OD	Mild†	Mild	Observe	PND	−	+
Case 3						
OD	Threshold	Prethreshold	Laser	Observe	+	+
OS	Threshold	Prethreshold	Laser	Observe	+	+
Case 4						
OD	Threshold	Prethreshold	Laser	Laser	+	+
OS	Threshold	Threshold	Laser	Laser	+	+
Case 5						
OD	Threshold	Prethreshold	Laser	PND	+	+
OS	Threshold	Threshold	Laser	Laser	+	+
Case 6						
OD	Threshold	Prethreshold	Laser	Observe	+	+
OS	Threshold	Prethreshold	Laser	Observe	+	+
Case 7						
OD	Stage 5	RD	VIT	VIT	+	+
OS	Stage 5	RD	VIT	VIT	+	+
Case 8						
OD	Stage 4A	Stage 4A	VIT	VIT	+	+
OS	Stage 4A	No RD	VIT	Observe	+	+
Case 9						
OD	Stage 4B	Stage 4B	VIT	VIT	+	+
OS	Stage 4A	Stage 4B	VIT	VIT	+	+
Case 10						
OD	Stage 4A	Stage 4A	SB	PND	+	+
OS	No RD	unable to determine	Laser	PND	+	+

*Meeting CRYO-ROP definition (REF).

†Not meeting CRYO-ROP definitions for prethreshold or threshold ROP (REF).

+ = present; − = absent; on-site = UCLA; PND = decision pending further examination; RD = retinal detachment; remote site = Royal Oak, MI; SB = scleral buckle; VIT = vitrectomy.

identified by the telemedical consultants in 18 of 19 (95%) eyes. One eye (patient 2; see Table 1) was believed to have Plus disease by the telemedical consultants and not by the local consultants.

The presence of prethreshold or threshold disease as defined by the CRYO-ROP Study or the presence or absence of RD was evaluated by both local and remote consultants. Remote telemedical evaluation agreed with on-site evaluation in 17 of 19 (89%) eyes (Table 1). The left eye of patient 8 was noted to have a peripheral stage 4A RD by conventional examination, but telemedical evaluation did not recognize the RD. The left eye of patient 10 was diagnosed with threshold disease by conventional means, whereas the telemedical evaluation was inconclusive as to the presence of threshold disease.

Management decisions were also compared between the centers (Table 1). In seven eyes remote consultants recommended observation, whereas the on-site consultants decided to treat the same eyes with either laser or vitrectomy. In 6 of 7 (86%) of these eyes the remote consultants diagnosed prethreshold disease and recommended repeat examination, whereas the on-site consultants diagnosed and treated threshold disease. The one remaining eye in this group had a stage 4A RD that was not detected by the telemedical consultants. This eye went on to undergo lens-sparing vitrectomy.

Image quality precluded the remote consultants from generating treatment recommendations in four eyes. In two of the four eyes both remote examiners made accurate diagnostic evaluations but were not comfortable making a treatment recommendation without further examination.

Both remote examiners preferred the zip drive archiving to the internet file transfer protocol site, noting delays in accessing data because of bandwidth limitations.

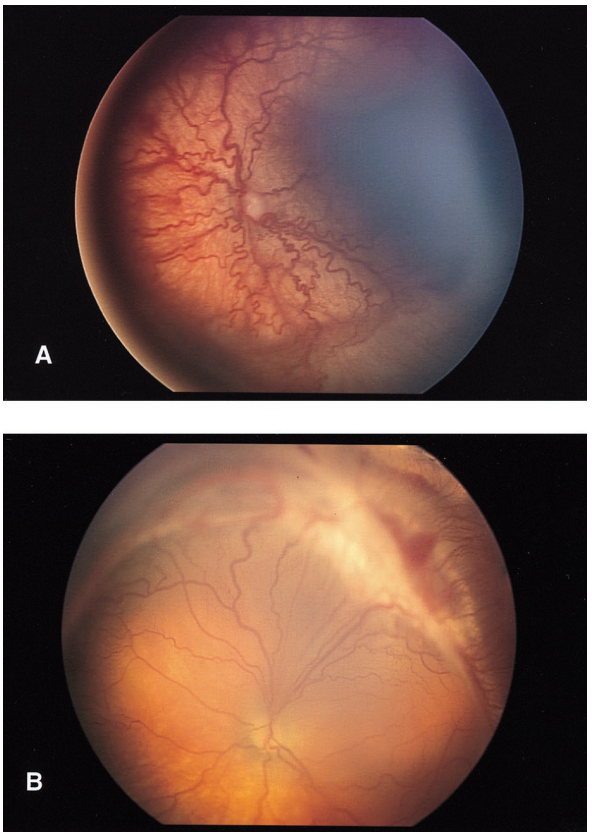

Figure 1. RetCam 120 images. **A**, Stage 3+ ROP. **B**, Stage 4A ROP.

Discussion

The drive to take better care of our patients, shrinking resources, increasing patient populations, and liability issues are pushing medicine into the digital age. Digital information management and telemedicine have been proposed as potential solutions for the problems facing the management of ROP.

In this study we have shown that given adequate image acquisition, image transmission (bandwidth), and clinical expertise, remote diagnosis and management of ROP is possible. Furthermore, we have demonstrated that this telemedical strategy may be highly accurate as a screening tool when assessing whether a child's eye requires the urgent attention of a physician capable of evaluating and managing threshold ROP. Of particular importance is the 95% sensitivity or accuracy in the detection of Plus disease. Plus disease is necessary for the diagnosis of threshold ROP by the CRYO-ROP definition and is widely accepted as the sign that signals the need for treatment. Thus, the fact that Plus disease was readily diagnosed telemedically demonstrates the potential of this strategy.

The results of this investigation also demonstrate the ability of a remote consultant to diagnose RDs and make accurate surgical recommendations. The lower rate of accurately identifying RD telemedically and the corresponding management recommendations point out strengths and weaknesses of this telemedical strategy. The strengths are that RD can be diagnosed and the decision for surgery made, thus as a screening tool this strategy may prove powerful. On the other hand, it was more difficult to precisely grade each detachment and to precisely agree on which surgery should be performed. The lack of stereoscopic imaging may decrease the likelihood of detecting subtle RD. This may have more to do with surgeon differences than with image quality or telemedical accuracy.

The weaknesses of this study are the relatively small number of patients studied and the fact that actual treatments were not based on telemedical evaluations. Thus, outcomes can only be discussed theoretically. In other words, one might propose that the outcome for a child's eye would be similar if the decision to treat threshold ROP is made telemedically or on site, assuming the quality and timing of treatment are constant. On the other hand, this study was not designed to evaluate treatment outcomes, nor was it designed to statistically prove the safety and efficacy of this strategy. This investigation was designed to evaluate the accuracy of telemedical diagnoses and treatment plans as they compared with standard of care on site. Another weakness of the study is that almost all the eyes in this study (17 of 19; 89%) had at least prethreshold ROP. Thus, the population evaluated does not reflect a typical screening population. On the other hand, 7 of 19 (37%) eyes did not have threshold disease, but rather, had RD. Furthermore, an additional eye had only mild ROP (stage 1). The eye with RD and the eye with stage 1 ROP can be considered an internal control group (eyes without threshold disease).

In our study, management decisions made by the remote observers were less accurate than their diagnostic evalua-

tions. This discrepancy may be related to intercenter bias with regard to early treatment vs. strict adherence to CRYO-ROP guidelines, lack of stereophotographic imaging, or inadequate image acquisition. In any case, the remote detection of Plus disease, if appropriate screening protocols were followed, would have initiated prompt referral for an on-site evaluation. Given our results, we recommend that all treatment decisions be based on the findings of on-site standard of care evaluations.

The strengths of this study are many. First, the proof of principle is established. ROP can be remotely evaluated and accurate diagnosis is possible. Of primary importance is the accurate diagnosis of Plus disease and the potential for accurate ROP screening. Ideally, the telemedical strategy used in this trial could be modified to include nonophthalmic personnel acquiring the images and transmitting them to remote experts. Studies investigating the use of nonophthalmic personnel are underway. Theoretically, with accurate screening strategies and prompt referral patterns, severe visual loss from ROP can be greatly reduced.

Despite the potential for greatly reducing visual loss from ROP, many technical and ethical issues remain. The technology to provide telemedical care exists. Yet, the issues of convenience, speed, privacy, and reliability of the transmission are yet to be systematically studied. Furthermore, the image acquisition unit is still in its first generation. Tremendous improvements are expected that should continue to simplify and improve image acquisition. Last, the medical ethics and medical-legal issues of telemedicine have yet to be fully explored by the medical community or society at large. Nonetheless, this new technology, the RetCam 120 digital fundus camera, can acquire accurate panoramic views of the neonatal fundus in a digital format sufficient for the telemedical evaluation and management of ROP. With the potential for improved ROP screening and decreased visual loss in our pediatric population, the need for future study is certain.

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