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Tele-Optometry and Mobile Diagnostic Clinics: A Model for Addressing Barriers and Expanding Access to Eye Care in Rural and Underserved Population in the United States

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Abstract

Access to comprehensive eye care remains a persistent challenge in rural and underserved population across the United States due to geographic isolation, provider shortages, and socioeconomic barriers. In this narrative review, we describe how tele-optometry and mobile diagnostic clinics are becoming mainstream models to address these inequalities and to increase access to vision care. Tele-optometry uses synchronous and asynchronous digital platforms for remote eye exams, triage and specialist consultations while mobile clinics provide diagnostic services for retinal imaging, refraction and intraocular pressure testing directly to the communities, schools and senior centres. When tele-optometry and mobile diagnostic clinics are combined, they offer a hybrid model of care that combines in-person diagnostic capacity with remote reach and efficiency. This helps increase screening rates, shorten diagnostic times and earlier detect sight-threatening diseases such as diabetic retinopathy and glaucoma. This paper reviews the ways this model can be deployed such as community-based partnerships, school-based outreach and partnerships with public health initiatives. These models are really promising but have some issues they face, like technological and financial limitations, data security and privacy issues and other challenges that must be addressed to have good success. This review identifies future directions including artificial intelligence, integration with existing healthcare systems and longitudinal and cost-effectiveness studies. In all, tele-optometry and mobile diagnostic clinics represent an important shift toward a more accessible and patient-centered eye care delivery. Their strategic integration in national health systems could help reduce preventable vision loss and achieve long-term public health goals based on health equity and accessibility.

Subject Areas

Optometry & Ophthalmology

Keywords

Tele-Optometry, Mobile Diagnostic Clinics, Underserved Populations, Preventable Blindness, Public Health

1. Introduction

Access to comprehensive eye care is still an important public health issue in the United States, especially for rural and medically underserved populations. Lack of eyecare service increases the risk of preventable vision loss in rural, low income and minority communities [1] [2]. These communities tend to be systemically excluded from comprehensive eye care and face barriers due to geographic isolation, provider shortages, inadequate insurance coverage and socioeconomic disadvantages preventing timely access to preventive and curative vision services [3] [4]. The consequences are severe as uncorrected refractive errors, diabetic retinopathy, glaucoma and other sight threatening conditions are often not diagnosed until they advance to more severe stages or cause total vision loss. Tele-optometry and mobile diagnostic clinics have recently emerged as promising models to tackle these inequities, by using tele-optometry to remotely provide clinical optometric services and using mobile eye clinics to offer on-site diagnostic and treatment services to underserved populations [5] [6]. Together, these models can circumvent geographic and logistical constraints and have already shown to increase screening rates, reduce delays in care and improve health outcomes. This review explores, tele-optometry and mobile diagnostic units, its current state of the art and challenges to its implementation in underserved areas in the United States. We draw together findings from recent studies and public health interventions to form a framework for integrating these technologies in mainstream care delivery to reduce avoidable blindness and promote vision equity.

2. Tele-Optometry: Concepts, Tools and Models

Tele-optometry is the remote provision of optometric services over telecommunications networks. This allows clinicians to perform visual acuity tests, refraction, intraocular pressure assessment, anterior and posterior segment evaluations and patient counseling over long distances [5]. Tele-optometry has become popular especially since the COVID-19 pandemic and it has gained significant relevance as a way of expanding care to previously underserved areas.

Tele-optometry uses two main modalities:

- Synchronous (real time) consultations which involve live video interactions between patients and optometrists or ophthalmologist. They help triage urgent eye issues, perform follow-up consultations, report and discuss results [1].

- Asynchronous (store-and-forward) imaging, allows on-site technicians or mobile units to take portable retinal and anterior segment images for later review by an optometrist or ophthalmologist. This model is especially useful for mass diabetic retinopathy screening programs and glaucoma surveillance [7]. These images can also be filtered through AI to detect retinal pathologies like diabetic retinopathy and age-related macular degeneration [8].

3. Mobile Diagnostic Clinic Deployment Strategies, Impact and Public Health Implication

Mobile diagnostic clinics open up eye care to populations who might otherwise be excluded from traditional clinic visits. These mobile clinics usually have diagnostic tools like autorefractors, fundus cameras, tonometers and other portable devices for eye exams. Mobile clinics may serve rural areas, low-income neighborhoods and other underserved areas without patients having to travel to far distance for care. Because they provide on-site diagnostics and treatment, these clinics address geographic and logistical barriers to eye care [5]-[7]. Such clinics may have vehicles that are used to travel to different locations such as going to schools, nursing homes or community centers and provide all kinds of essential eye care services that are tailored to the specific needs of each local population and the deficiency they face, such as vision screenings, refraction tests, retinal photography, glaucoma screening, patient education and follow up services.

3.1. Deployment Strategies

Successful deployment of mobile diagnostic clinics is dependent on some factors such as strategic planning, local partnerships and resource allocation. Common deployment strategies include:

3.1.1. Community-Based Partnership

Some mobile clinics serve local health departments, community health centers and schools for eye care. Working with reputable community groups, mobile clinics can dispel skepticism and build trust with these underserved populations. In rural and tribal areas, for example, community-based mobile units reduce unaddressed vision problems by almost one third [3].

3.1.2. Scheduled and On Demand Service Models

Mobile clinics might have a set schedule and visit certain places like schools, senior centers and churches on certain days, or they may be on call and serve local needs as they arise. The flexibility of on-demand services also allows these clinics to respond to public health emergencies during pandemics or natural disasters [6].

3.1.3. Technology Integration

Mobile diagnostic clinics are increasingly adding tele-optometry tools like remote consultation platforms and AI-assisted diagnostic tools. With these recent technologies mobile units can provide tele-optometric services and immediate expert consultation which helps to expand the range and effectiveness of care delivered.

Remote connectivity also enables collaboration with specialist care providers who can help in real time [7].

3.1.4. Collaboration with Telemedicine Programs

Many mobile eye clinics are connected to telemedicine initiatives that allow data to be sent to larger health systems for review and referral. This model supports integrated care by connecting patients who need further diagnostic testing or treatment with specialists promptly [1].

3.1.5. Partnership with Public Health Initiatives

Mobile eye clinics often work with public health programs to address common vision problems like diabetic retinopathy, glaucoma and age-related macular degeneration. This raises awareness of eye health and gets community members screened regularly [3].

3.1.6. School-Based Programs

Some mobile eye clinics cater to school children and offer vision screenings as part of annual health checks. Such an approach identifies children with refractive errors, amblyopia and other vision problems that impair educational performance. Such programs are particularly important in rural or otherwise underserved areas where children may not have regular eye exams [6].

3.1.7. Partnership with Non-Profit Organization

A few non-profits have mobile clinics that provide free or low-cost eye care to people with low-income or no income at all. All these collaborations make eye care more accessible even for those without insurance [5].

3.2. Impact on Eye Care Access

Mobile diagnostic clinics have shown to improve eye care access and quality in underserved communities. Studies show that such mobile clinics can increase screening for conditions like diabetic retinopathy and glaucoma that are common in populations with poorer access to routine eye care. [7] For example, mobile units performing retinal screenings in rural settings have raised the detection rate of diabetic retinopathy earlier and reduced the risk of vision loss [3]. Mobile clinics may also help ease the economic burden of untreated vision problems by preventing costly late-stage eye diseases. Early detection and prompt treatment of conditions such as cataracts, glaucoma and macular degeneration can prevent long-term disability and reduce expensive surgeries and treatments [6]. Mobile clinics also promote health equity by providing care where it is needed most. Health education and community outreach through mobile clinics also help patients get essential services closer to home, as well as promote preventive care and health literacy [8].

3.3. Case Studies Demonstrating the Impact of Mobile Diagnostic Clinics

Empirical evidence from various programs across the United States demonstrates

that mobile diagnostic clinics can significantly enhance access to eye care in underserved populations. These case studies show the potential of mobile and hybrid care models to improve early detection of ocular diseases, reduce costs, and promote health equity.

- One such example is the Vision Van initiative by the American Optometric Association (AOA), which has served over 100,000 patients nationwide, particularly in post-disaster and high-need areas. The mobile unit offers comprehensive eye exams and has identified untreated refractive errors in approximately 33% of patients, and sight-threatening conditions in an additional 12%. Notably, 60% of those served reported not having had an eye exam in more than five years, highlighting the critical reach of the program [9].
- Similarly, in rural North Carolina, a tele-ophthalmology-integrated mobile diagnostic program targeting diabetic retinopathy screening demonstrated a 70% increase in screening uptake within two years. Approximately 17% of screened individuals were newly diagnosed with moderate to severe diabetic retinopathy. Additionally, this program reduced referral-to-diagnosis times by 45% through asynchronous imaging and remote review, and it achieved estimated cost savings of $220 per patient by preventing progression to advanced disease [10].
- The See to Succeed program in Houston, Texas, exemplifies a school-based mobile eye care model. Operating in Title I schools, the program screens more than 65,000 children annually. Between 25% - 30% of children screened required corrective lenses, and 97% of those who received glasses reported improved academic performance and concentration. This shows the broader educational and developmental benefits of accessible eye care in underserved pediatric populations [11].
- Among Native American populations, the Navajo Nation Mobile Eye Clinic Project combines mobile diagnostics with tele-optometry to address longstanding barriers to care. Over a three-year period, the program reached more than 8000 individuals across tribal lands. It identified over 700 cases of previously undiagnosed glaucoma and diabetic eye disease, with patient satisfaction rates exceeding 90% due to reduced travel requirements and culturally sensitive care delivery [12].
- Finally, the U.S. Department of Veterans Affairs (VA) implemented a mobile tele-optometry program to address eye care access among rural veterans in the Midwest. The program increased screening rates for diabetic eye disease by 35% and reduced appointment wait times from an average of 45 days to under 10 days. Financial analyses revealed that the program saved over $1.5 million annually, primarily through decreased travel reimbursements and early intervention [13].

Collectively, these case studies illustrate that mobile diagnostic clinic, especially when integrated with tele-optometry, are both clinically effective and economically efficient. They facilitate early diagnosis of preventable eye conditions, mini-

mize logistical barriers to care, and promote sustainable health outcomes in vulnerable populations. These findings provide a compelling basis for the broader adoption and policy support of hybrid mobile tele-optometry models in national public health strategies.

3.4. Policy and Public Health Implications

Tele-optometry and mobile diagnostic clinics not only represent novel delivery models but are also vital in achieving several US public health goals. Through improved access to eye care, health equity and preventative measures these models can contribute to national public health goals like those mentioned in the Healthy People 2030 which outlines the national health goals for the decade and is focused on reducing health disparities and improving access to healthcare and preventing vision loss in underserved populations [14]. Also, it contributes to achieving goals for improving access to health services in medically underserved areas set by the Health Resources and Services Administration [15]. In addition, their wide adoption could lower long-term healthcare costs and improve health for underserved populations. Preventative eyecare can watch many patients detecting conditions early before they lead to severe stages or even vision loss and the associated high cost of managing advanced diseases [16].

4. Synergy between Tele-Optometry and Mobile Diagnostic Clinics

Combining tele-optometry with mobile diagnostic clinics may reduce barriers to eye care in underserved populations. By combining mobile unit's flexibility and mobility with telemedicine capabilities, these hybrid models of care are able to broaden the reach, effectiveness and continuity of eye care services in rural or other resource poor settings. Mobile diagnostic clinics may become physical tele-optometry hubs, with on-site technicians performing initial screenings and tests while patients are simultaneously seen remotely by specialized eye care professionals. Therefore, this hybrid model combines the benefits of both in-person care (*i.e.*, with access to diagnostic equipment and eye exams) and telemedicine (*i.e.*, with access to specialists and advanced consultation) to provide a comprehensive and accessible eye care to all. One example of how this workflow might look in a hybrid model combining tele-optometry and mobile clinics is this:

- Screening: A patient visits a mobile clinic in a rural town. The technician does visual acuity tests, retinal photography and tonometry (for intraocular pressure) among other diagnostic tests. These results get automatically uploaded to a secure cloud or telemedicine software and sent to an eye care specialist.
- Remote Consultation: The patient then has real-time remote consultation with an ophthalmologist or an optometrist who is at a central hub located maybe in an urban area. The specialist shows the test results, makes a diagnosis and discusses treatment with the patient. This can be a video consultation where the patient is advised on diagnosis, treatment plan and recommendations even if

he is far away from the specialist.

- Referral or Treatment: When testing or special treatment is needed at the consultation it is referred to another ophthalmologist or eye care facility. Staff at the mobile clinic communicate with the referral and tell the patient what to do. If the patient also needs glasses, the mobile clinic may give immediate corrective lenses or eyewear [17].

This workflow is ideal because it combines the advantages of tele-optometry and mobile clinics to give the best possible care. It cuts wait times, and patients do not have to travel far, they get specialist care faster, and the treatment decisions are made quicker.

5. Barriers to Implementation

Integration of tele-optometry and mobile diagnostic clinics offers a way forward to improve eye care for the underserved but there are still challenges that need to be solved. The major challenges are technological and financial limitations, and privacy and data security issues. Other challenges include workforce adaptation, patient engagement, community awareness, poor integration with primary care providers as well as regulatory and reimbursement challenges. So, these issues have to be resolved for the viability and sustainability of this hybrid model.

5.1. Technological and Financial Barriers

Technologically, limited internet infrastructure remains a critical obstacle. Many rural and tribal regions across the United States lack the broadband capacity necessary for real-time (synchronous) telemedicine consultations. In response, programs have adopted asynchronous (store-and-forward) technologies that allow technicians to capture retinal and anterior segment images locally and transmit them for later review by specialists. For example, the Navajo Nation Mobile Eye Clinic Project utilized asynchronous image transfer due to low-bandwidth conditions, allowing continued service delivery despite infrastructure constraints [12]. In addition, the high cost and maintenance of portable diagnostic equipment such as handheld fundus cameras, autorefractors, and tonometers can limit the reach of mobile clinics. Smaller or community-based programs often cannot afford the initial investment or the ongoing calibration and repair costs. Nevertheless, innovations in compact, battery-operated devices have partially alleviated this issue. The American Optometric Association's Vision Van, for instance, employs solar-powered charging systems and lightweight, portable equipment that make service delivery feasible in disaster zones and remote settings [9].

Financially, tele-optometry faces reimbursement challenges. Inconsistent Medicaid and Medicare policies across states often result in limited or no coverage for remote optometric consultations or mobile-based services. A 2021 analysis by the Center for Connected Health Policy revealed that only 16 states provided Medicaid reimbursement for tele-optometry services, significantly restricting scalability. In response, many mobile initiatives rely on cross-sector partnerships and

grant-based funding. The See to Succeed program in Houston, for instance, operates in over 100 Title I schools annually through support from local government agencies, nonprofits, and private donors, offering free or low-cost vision screenings and corrective lenses to underserved children [11].

Moreover, integrating community health workers and local technicians into service delivery has proved both cost-effective and culturally appropriate. The North Carolina diabetic retinopathy screening program trained nurses to perform fundus imaging, thereby reducing staffing costs while improving local engagement and trust [10].

By leveraging asynchronous technologies, innovative device design, strategic partnerships, and community-based staffing, tele-optometry and mobile diagnostic clinics have demonstrated resilience and adaptability in overcoming these structural and financial limitations.

5.2. Data Security and Privacy Challenges

The expansion of tele-optometry and mobile diagnostic services introduces new complexities regarding data security and patient privacy. These models often depend on the transmission and storage of sensitive health information, including retinal images, diagnostic results, and patient identifiers, across wireless networks and cloud-based platforms. Consequently, ensuring compliance with the Health Insurance Portability and Accountability Act (HIPAA) and related data protection standards becomes both essential and challenging. One of the principal concerns is the vulnerability of data when transmitted from remote or mobile settings with inadequate cybersecurity infrastructure. Mobile diagnostic units operating in rural or disaster-stricken areas may lack secure internet connections, increasing the risk of data breaches during upload or remote consultation sessions. Additionally, the integration of third-party cloud platforms to store or transmit patient data introduces risks related to data sovereignty, platform reliability, and accountability in the event of breaches. Some mobile clinics have addressed these challenges by implementing offline data capture tools that store encrypted information on secure local devices until internet access becomes available, at which point the data is securely uploaded to a centralized system. However, this solution requires consistent staff training in data handling protocols and regular system audits to ensure compliance. Furthermore, tele-optometry platforms often involve multiple stakeholders including technicians, optometrists, ophthalmologists, and IT providers raising questions about access controls and data sharing permissions. Without clear governance frameworks, there is potential for misuse or mishandling of patient information. Ensuring role-based access control, multi-factor authentication, and audit trails is therefore essential to protecting patient confidentiality. Finally, the lack of standardized telehealth regulations across states complicates the enforcement of uniform privacy protections. Variability in consent requirements, data retention policies, and breach reporting laws means that mobile and tele-optometry programs operating across multiple jurisdictions must

navigate a fragmented regulatory landscape. This fragmentation not only places an administrative burden on program administrators but also increases the risk of noncompliance.

Addressing these privacy and data security concerns is crucial for building trust among patients and providers, ensuring ethical practice, and safeguarding the long-term viability of tele-optometry models. Investment in cybersecurity infrastructure, staff training, standardized policies, and regulatory harmonization will be necessary to support the secure expansion of these critical health services.

6. Future Directions and Research Gaps

As tele-optometry and mobile diagnostic clinics are gaining ground as models for improving eye care access there are several key areas that need further study to make them more effective and adequately fit into the existing healthcare system. In order to advance the field and make these models fit for widespread adoption future research should focus on longitudinal studies, cost-effectiveness evaluations, AI integration, interoperability with electronic health records (EHRs) and strategies to fund these models going forward. Also, policymakers, educators, eyecare professionals and researchers must identify gaps and solutions to make the technologies work.

6.1. Need for Longitudinal Studies and Cost-Effectiveness Data

Early results show that tele-optometry and mobile diagnostic clinics can improve care access and cost but longer-term results need to be assessed. Specifically, studies should assess long-term health outcomes in patients seen by tele-optometrists and mobile clinics in terms of prevention of vision impairment, quality of life and decreased incidence of advanced eye diseases [18]. Cost-effectiveness analyses should also compare the total financial impact of these models to traditional in-person care in terms of operation costs, patient outcomes and the possibility of avoiding more expensive treatments [19]. These studies should demonstrate whether the models can be economically scaled in different settings, and how cost sharing would allow people and communities to get these services without huge out of pocket costs [20].

6.2. Integration with Artificial Intelligence and Existing Healthcare Systems

Future research areas should focus on the integration of artificial intelligence and Machine learning in tele-optometry and mobile Diagnostics. AI can automate image analysis and decision making for diagnostic procedures such as fundus imaging, visual acuity test, refraction [21]. AI-driven tools may identify eye conditions more accurately than human clinicians in remote settings where trained professionals are not readily available. In addition to that, tele-optometry platforms need to be integrated into existing healthcare systems and linked to electronic health records to ensure continuity of care and this can be done through strategic collab-

oration with primary care providers and specialists, improving care coordination and access in underserved areas. These clinics work closely with primary care physicians to receive referrals for high-risk patients such as those with diabetes or hypertension and conduct on-site screenings, with results often shared through interoperable electronic health record systems. Programs like North Carolina's diabetic retinopathy screening initiative demonstrate how such collaborations can reduce unnecessary referrals and facilitate timely specialist consultations. Similarly, the Veterans Health Administration has integrated mobile eye units with its telehealth infrastructure to serve rural veterans, enabling remote specialist evaluations and seamless data exchange. In California, platforms like EyePACS support this integration by allowing mobile units to upload retinal images for remote review, while in Texas, the See to Succeed program co-locates mobile vision services within school-based health centers to provide comprehensive care. These examples highlight the potential for mobile diagnostic clinics to enhance continuity of care and deliver accessible, interdisciplinary eye health services within broader public health frameworks. Therefore, integration would allow effective sharing of patient data, improving clinical workflows and follow-up care because eye health information would be available to all primary care providers and specialists [22]. In future studies it will be good to find out other ways these technologies may be further incorporated into the current healthcare system and even what regulatory frameworks are needed to protect patient and data privacy [23].

6.3. Recommendations for Policymakers, Educators, and Researchers

Policymakers, educators and researchers play a critical role in shaping the future of tele-optometry and mobile diagnostic clinics. Policymakers should prioritize regulatory reforms to increase access to tele-optometry services through standardization of reimbursement policies and licensure portability as well as telemedicine practice guidelines [24]. Interstate licensure agreements and uniform telemedicine regulations would make tele-optometry services available across state lines in areas where there is a shortage of eye care professionals.

Educators should train the next generation of healthcare professionals to deliver tele-optometry and run mobile diagnostic clinics. For example, telemedicine training should be incorporated into optometry and ophthalmology curriculum and ongoing professional development for current practitioners should be provided [19]. Educators should also stress digital literacy and train healthcare workers on how to engage patients in remote settings.

For researchers, that means they need to continue to explore on areas such as patient engagement, technology adoption and health equity and these have to stay on their research agenda. Studies should examine factors affecting patient acceptance of tele-optometry and mobile clinics, especially among low income and ethnically diverse groups [25]. Research on digital health literacy is also needed to build patient trust and overcome technology adoption barriers in underserved

communities.

7. Conclusions

Tele-optometry and mobile diagnostic clinics are emerging solutions to eye care challenges in underserved and rural areas. These models can significantly help to broaden access to essential eye health services for populations who otherwise would have great difficulty getting timely care because of distance, cost or scarcity of trained personnel. But by applying telemedicine and mobile health technologies, these efforts can provide quick, low-cost eye care services to people even in those remote areas. However, for these steps to be fully effective, the healthcare system must however adopt scalable and equitable models that will thrive and overcome limitations while also making these services and innovations accessible to all especially the poorest and most vulnerable communities.

Looking forward, we need more innovation, collaboration and research to improve these models and close the gaps in patient engagement, technology adoption and policy support. Politicians, health care providers and researchers must work together to make tele-optometry and mobile clinics more than just supplementary services but a major part of a modern healthcare system. The future of eye care lies in these innovative, hybrid models, as they have the potential to drastically improve health outcomes, reduce healthcare disparities, and inequalities while creating an accessible and universal system of eye care for all Americans.

Conflicts of Interest

The author declares no conflicts of interest.

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