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Maternal telehealth: innovations and Hawai‘i perspectives

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Abstract: Access to maternal-fetal medicine (MFM) subspecialty services is a critical part of a healthcare system that optimizes pregnancy outcomes for women with complex medical and obstetrical disorders. Healthcare services in the State of Hawai‘i consist of a complicated patchwork of independently run community health clinics and hospital systems which are difficult for many pregnant patients to navigate. Maternal telehealth services have been identified as a solution to increase access to subspecialty prenatal services for women in rural communities or neighboring islands, especially during the COVID-19 pandemic. Telehealth innovations have been rapidly developing in the areas of remote ultrasound, hypertension management, diabetes management, and fetal monitoring. This report describes how telehealth innovations are being introduced by MFM specialists to optimize care for a unique population of high-risk patients in a remote area of the world such as Hawai‘i, as well as review currently available telemedicine technologies and future innovations.

Keywords: Hawai‘i; maternal health; obstetrics; remote fetal monitoring; rural health; telehealth.

Introduction

Maternal-fetal medicine (MFM) is a subspecialty of obstetrics and gynecology which provides essential perinatal

healthcare services to optimize high risk pregnancies. The State of Hawai‘i, which spans six publicly-inhabited islands, is a complicated patchwork of in-patient and out-patient healthcare systems which are loosely affiliated. Out-patient healthcare consists of a variety of community health clinics which are primarily Federally Qualified Health Centers (FQHC) and Native Hawaiian Health Centers (FQHC look-alikes) that are intermixed with independent private practitioners and health system-employed provider groups that are distributed across the six islands. There are five hospital health systems that provide obstetric services, with minimal coordination across systems and poorly defined integration with the outpatient clinics in rural areas and neighboring islands. This demonstrates the need for an improved and coordinated maternal-fetal healthcare system across the State of Hawai‘i, USA.

Throughout the state, which comprises 1.4 million inhabitants [1], there currently exists only one Level 2 maternity hospital, Kapi‘olani Medical Center for Women and Children (KMCWC) that is available to provide subspecialty maternal-fetal health care and obstetrical services for any maternity patient with high-risk pregnancies, regardless of ability to pay and regardless of health plan. The other hospitals with neonatal intensive care units (NICU) and MFM subspecialist support are the Tripler Army Medical Center (TAMC) which provides maternity care for active duty service persons and their families, and the Kaiser-Permanente Health System which provides maternity care only for subscribers of their insurance plan. The state has a birth rate of 17,000 births per year [2], and an estimated 4,000 pregnant women in the state must travel to access its only Level 2 maternity hospital for crucial services, including prenatal ultrasounds and high-risk pregnancy care. Interisland travel typically consists of fixed-wing airplane travel (\$100–300 per round trip) [3], taxi or rideshare services (approximately \$75 for a one-way trip from Honolulu International Airport to Waikiki) [4], and lodging, which makes access to subspecialty maternity care (e.g., hypertension, diabetes, mental health, prematurity prevention services) and basic prenatal ultrasound examinations a burden for a large portion of Hawai‘i’s pregnant women, and therefore poses a significant public health issue.

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Telehealth services can be provided remotely through technology supporting telecommunication between patient, provider, and healthcare system and consist of three general types of services: (1) video conferencing and consultations; (2) remote patient monitoring; and (3) tele-imaging. Prior to the COVID-19 pandemic, prominent telehealth services that were being utilized across the State of Hawai'i included behavioral and stroke telehealth. However, since over 90% of Hawai'i's land mass is rural [5], expanding access to prenatal services was considered the next frontier for developing maternal telehealth services. Maternal telehealth services are an opportunity to better coordinate the delivery of maternal healthcare, particularly in rural and non-contiguous states and territories in the USA. In order to assess the value, enhancements, and barriers to the implementation of maternal telehealth services, a multidimensional needs assessment was conducted, including a conference, surveys, MFM site visits, and focus group discussions. The utilization of remote telehealth services has boomed with the COVID-19 pandemic, revealing Hawai'i's gaps in healthcare and readiness to adopt innovative telehealth services, which can be used to optimize maternal and fetal health.

The process of telehealth infrastructure formation since 2019 in Hawai'i is shown in Figure 1.

Hawai'i maternal telehealth summit

The first Hawai'i Maternal Telehealth Summit was convened on October 9, 2019 with generous grants from the State of Hawaii Department of Health, the Hawai'i Section of the American College of Obstetrics and Gynecology, the University of Hawai'i Department of Obstetrics and Gynecology and Women's Health, and the Pacific Basin Telehealth Resource Center (PBTRC). The overarching goals of this Summit were to (1) present telehealth "best practices" to key stakeholders and potential users of a state-wide maternal telehealth network, (2) conduct a needs assessment to determine current and future infrastructure needs for maternal telehealth services. The summit invited key stakeholders, including OB/GYN physicians from the John A. Burns School of Medicine, Hawai'i Pacific Health leadership, the Queen's Healthcare System Telemedicine leadership, Hawai'i Healthcare Systems Corporation staff, the State of Hawai'i Department of Health Maternal Health Division, neighbor island radiology providers, Hawai'i health plan representatives, telehealth champions from Federally-Qualified Healthcare Centers (FQHCs) from neighboring islands, Project ECHO

staff, University Health Partners Information Technology staff, Hawaiian Telecom representatives, staffers from Hawai'i state legislators, leadership from the University of Hawai'i, and the Lieutenant Governor of the State of Hawai'i. Over 90 attendees representing the six inhabited islands of Hawai'i participated in this three-day forum. The first day consisted of presentations on "best practices" from rural America and rural Lana'i Island. The founder of the Antenatal and Neonatal Guidelines, Education, and Learning System (ANGELS) program, a Medicaid-funded telehealth program for high-risk pregnancy patients across the State of Arkansas presented how telehealth could be used to provide subspecialty care access in rural regions and shared operational details of best practices of a variety of modes of maternal telehealth services that have been implemented across the rural State of Arkansas. The components of building telehealth infrastructure, including sonographer training; ultrasound equipment needs; reliable internet connection; personnel training; and a platform for image storage, charting, and information sharing were discussed. The local telehealth expert from the remote island of Lana'i shared the telehealth systems he had pioneered at the FQHC which included video visits and a chronic disease management program (CDMP) to remotely monitor blood pressures with a Bluetooth® interfacing blood pressure cuff and data storage program.

Attendees were surveyed about the resources and barriers they had with implementing maternal telehealth and the needs they faced in starting a maternal telehealth program at their location. Respondents reported barriers such as lack of telehealth infrastructure equipment and trained personnel, reliable internet connection, and questions facing insurance reimbursement, legal guidelines, and quality of care. Respondents expressed interest in a variety of innovative technologies including tele-ultrasound, mobile telehealth services such as texting and remote monitoring of vital signs, in-person scanning at remote sites, home visitation services, tele-consultations, phone consultations, and tele-genetic counseling services. Overall, there was a unanimous call for the creation of a maternal telehealth network providing ultrasound support for pregnant women from rural communities that would be overseen by University MFM physicians as a public utility or cooperative contract. In post-conference comments, participants noted the importance of extending access to maternal telehealth to Ni'ihau (a privately owned-inhabited Hawaiian island that is protected by the Hawai'ian people) and Hawai'i's incarcerated population. Comments also noted the need for a standardized telehealth billing and reimbursement

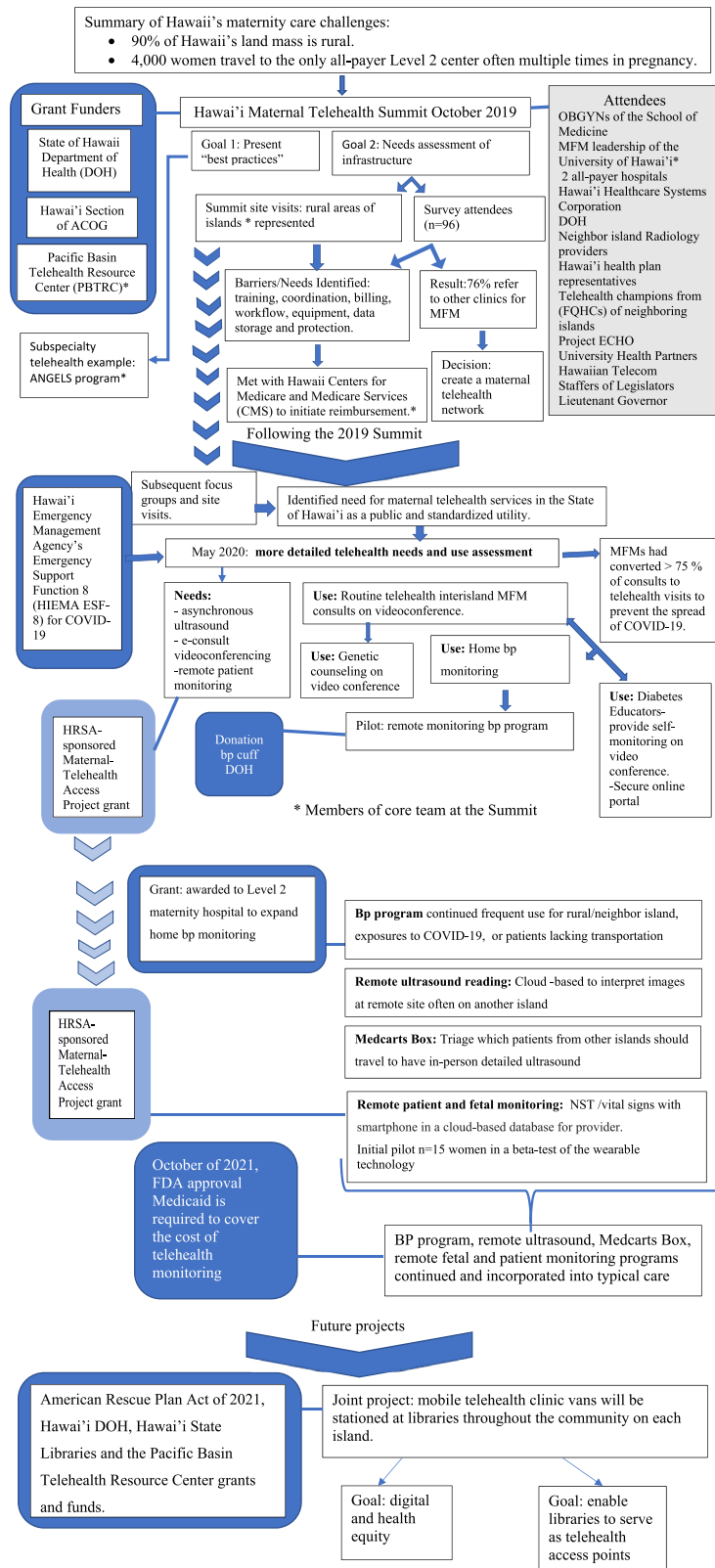


Figure 1: Process of telehealth infrastructure formation since 2019 in Hawaii'i.

system and more patient and community representation in assessing telehealth needs comprehensively.

During the Maternal Telehealth Summit that was described above, a survey was issued to elicit specific data addressing maternal telehealth. Of all responding providers, 76% reported referring patients to other clinics for MFM consultations or for further studies, including amniocentesis, chorionic villus sampling, doppler studies, fetal echocardiography, genetic counseling, and comprehensive ultrasound exams. The most commonly reported barriers to prenatal services included cost or lack of transport, lack of childcare, lack of support, and distance or length of travel. Overall, the survey results demonstrated a need to increase funding to support maternal telehealth services.

Focus group discussions and site visits demonstrated lack of specialty-trained personnel on neighbor islands (sonographers, genetic counselors, and MFM specialists), a lack of reliable broadband internet services, a lack of ultrasound image storage and reporting, a lack of telehealth equipment for real-time exams, and a lack of systemic funding, reimbursement, compliance, law, contracts, or care coordination. These focus group discussions highlighted the need for the implementation of maternal telehealth services in the State of Hawai'i as a public and standardized utility. Pilot projects to increase maternal telehealth services across the state of Hawai'i were then developed based on guidance of the surveys, focus group discussions, and site visits.

On the last two days of the Summit, representatives from the Pacific Basin Telehealth Resource Center, the MFM Leadership, and the ANGELS program conducted site visits to the Big Island of Hawai'i and rural O'ahu. The team also met with representatives of the Hawaii Centers for Medicare and Medicare Services (CMS) to initiate discussions regarding reimbursement for maternal telehealth services. The team learned that two of the critical access hospitals had aging ultrasound machines that did not have telehealth-compatible video and data ports to interface with broadband. They discovered that only Lana'i had a permanent sonographer who was trained in obstetrical ultrasound, but of retirement age; while Kauai's once multiple sonographers had since moved back to the US mainland leaving only one obstetrically trained sonographer. The site visits also demonstrated that one critical access hospital contracted with eight different telehealth platforms on the US mainland to provide care for patients in their remote area and those platforms were not interchangeable; and the two Federally Qualified Health Centers (FQHCs) providing detailed fetal ultrasound imaging had purchased their own image storage and

reporting system which could not be viewed by other providers who were outside of their network, even when the patients were traveling to another island for consultation.

Telehealth needs assessments

The Maternal Telehealth Summit conducted surveys of local practitioner concerns regarding the adoption of telehealth to guide future directions for the MFM Division and the PBTRC. Barriers preventing the initiation and expansion of telemedicine services included internet connectivity, staff training, equipment funding, workflow challenges, and licensing issues. Barriers to acquisition of telehealth equipment included price, lack of time, and lack of knowledge about how to acquire telehealth equipment. Identified training needs included patient training, physician and staff training, telehealth coordination, billing and reimbursement, workflow management, equipment management, and data storage, sharing, and protection. The largest barriers for patients included lack of telehealth knowledge, lack of appropriate technology, preference for in-patient visits, and being hearing- or sight-impaired. Of 93 respondents, 76% reported concerns about poor internet connection in their community.

In May 2020, a more detailed telehealth needs assessment was conducted by Hawai'i Emergency Management Agency's Emergency Support Function 8 (HIEMA ESF-8), which oversees Hawaii's medical care and public health, in response to the COVID-19 pandemic. This Survey reported an increase in audio and video patient visits, an increase in patient triage, and a desire for increased electronic consults (E-consults), asynchronous store-and-forward technology, and remote patient monitoring as a result of the COVID-19 pandemic.

Innovations in maternal telehealth

Maternal-fetal medicine consultations

Prior to the COVID-19 pandemic, telehealth video conferencing visits or virtual health visits between patients and providers were being used for less than 5 percent of prenatal consultations by the University MFM group. At the height of the COVID-19 pandemic, the University MFM providers had converted over 75 percent of their consultative visits to telehealth visits to prevent the spread of COVID-19 infection while minimizing public transportation and air travel from the neighbor islands. In addition to,

routine telehealth consultations from one island to a patient on another island, certified diabetes educators were trained to perform virtual training of pregnant patients to perform self-monitoring of blood glucose (SMBG) and insulin injections. The patients were also instructed on how to use the electronic patient portal on the secure online website to enter their SMBG fingerstick measurements for tracking and glucose management of gestational diabetes and Type 2 diabetes in pregnancy. Telehealth visits were also used for genetic counseling.

Remote ultrasound imaging

A store-and-forward software provides the platform for ultrasound images to be sent to a provider in an efficient manner. The store-forward asynchronous transmission has been implemented to communicate high-quality ultrasound images into cloud-based storage from neighboring islands. The MFM specialist is then connected to the Cloud by logging into a secure internet website to read and interpret ultrasound images (at the remote site) and generate a report. The report will be sent back to the originating health care provider site which can then be made a part of the patient record (at the originating site).

Medcarts

Medcarts support real-time telehealth consultation with two monitors. Medcarts support the real-time simultaneous ultrasound imaging and the live video of the patient and sonographer (at the originating site) and the provider (at the remote site). The remote MFM physician who is supervising the fetal ultrasound and providing counseling to the patient at the originating site, can use a dual monitor system to visualize the ultrasound image and teleguidance to direct the sonographer if necessary (e.g., “Show me the fetal lips and nose; show me the 4-chamber view of the heart again”). This system also gives the MFM provider the opportunity to communicate with the patient simultaneously using the video-conferencing application. This is especially helpful for the MFM physician who is at the remote site to point out and explain preliminary readings, as well as provide consultation to the patient who is receiving news about a newly discovered congenital fetal anomaly while still in the ultrasound suite at the originating site. This virtual teleconsultation that is integrated with live-feed ultrasound improves communication and the patient experience, and allows the subspecialist

to have the opportunity to triage which patients need to leave their island home and fly to Honolulu for confirmatory prenatal ultrasound examinations.

Hand-held ultrasound

Live imaging and tele-guidance mobile hand-held ultrasound allow for quick capture of fetal images to assist in triaging the next course of action. The hand-held ultrasound probe works with a mobile computing tablet to transmit images to the remote MFM for triage, as well as teleguidance with live real-time imaging. This is considered a synchronous application and was utilized by a traveling midwife provider who was providing home visitation patient evaluations that was being monitored by the MFM physician during the COVID-19 pandemic. The midwife and MFM were able to successfully diagnose pertinent findings such as a post-Cesarean incisional hematoma using the hand-held ultrasound.

Mobile telehealth

The Midwifery-Integrated Home (MI-Home) Visitation Program started in 2021 in Oahu offered home visitation by a certified nurse-midwife in collaboration with hospital-based MFM specialists using mobile telehealth technologies. The traveling midwife carried portable telehealth tools to assist the patient to access subspecialty services from the field. Using mobile telehealth equipment that could be carried in a backpack, the MI-Home midwife could provide increased access to subspecialty care such as substance use disorder, diabetes management in pregnancy, management of women at risk for preterm birth, unhoused pregnant women, and Native Hawaiian, Pacific Islander, Filipino and Black women with multiple social determinants preventing access to primary and subspecialty care.

The lessons and knowledge gained from the MI-home program are numerous. MI-home piloted telehealth, telecommunications, and remote patient monitoring which can be adopted for use in other remote communities to provide services that are unique to pregnant patients. It optimized cell phone and computer applications for arranging confidential transportation to appointments and utilized a Health Insurance Portability and Accountability Act (HIPAA)-secure texting platform. The texting platform allowed a free, confidential communication and

allowed for continuity of care between midwife provider, office coordinator and patients.

Besides optimizing applications for arranging transportation and a texting platform, the midwife also piloted innovative technologies in the field with support from the MFM physicians. These included remote ultrasound guidance to evaluate abdominal masses, remote fetal monitoring with the commercially available system, the performance of non-stress tests (NST) to assess fetal well-being, and other telehealth systems to assess vital signs from remote locations.

Remote fetal monitoring

During the advent of COVID-19 pandemic, the University Health Partners received a Health Resources Services Administration-sponsored Maternal-Telehealth Access Project grant to pilot a remote fetal heart rate monitoring program and equipment. Tele-electronic, cloud-based remote fetal monitoring with a blood pressure cuff is a physician-prescribed, pregnancy monitoring system. It allows women with high-risk pregnancies to collect their data and review their progress with healthcare providers from home via wearable sensor band, blood pressure cuff and cloud-based digital ecosystem for non-stress test (NST) antenatal monitoring of fetal well-being. The device sends the data to a smartphone to store in a cloud-based database, providing data on heart rate to a provider. During the initial pilot, 15 women participated in a beta-test of the wearable technology as a demonstration of its utility across the Hawaiian Islands. In October of 2021, the remote fetal monitoring equipment received Federal Drug Administration (FDA) approval for the performance of a 20-min non-stress test (NST), a common assessment of fetal well-being that is typically performed in a physician's office. Hawai'i Medicaid is required to cover the cost of telehealth monitoring including a storage of patient data, in this case vital signs and fetal heart rate and forwarding to the medical provider equivalent to the same services provided for in person care.

The provider obtains patient consent from the patient to be enrolled into the monitoring system on a secure password-protected website. The patient is issued a written patient electronic consent on their smartphone device with Bluetooth® capability when installing the application built into the system to participate in the remote monitoring program application and the provider also obtains verbal patient consent. The fetal heart tracing is stored in the cloud and readily accessible by the health

center staff and MFM consultants with secure login access to the website.

Home blood pressure monitoring

In 2020 during the height of the first wave of the COVID-19 pandemic, the University MFM division initiated a home blood pressure monitoring program to assess hypertension of pregnant and postpartum patients with a generous donation of free blood pressure cuffs from the Hawai'i State Department of Health. A foundation grant was subsequently awarded to Kapiolani Medical Center for Women and Children to expand the home blood pressure monitoring to pregnant persons who needed advanced nursing support in collaboration with the MFM physicians. This expanded blood pressure program allows for guided changes in anti-hypertensive medications. Once a prenatal or postpartum patient with hypertension is identified, an order is placed by the physician for nursing communication with the patient through a secure patient portal. This remote blood pressure monitoring program has been particularly useful for rural or neighboring island patients, patients with exposures to COVID-19 infection, or patients lacking transportation.

Future innovations

Mobile telehealth clinics

As part of a Hawai'i Department of Health Centers for Disease Control and Prevention (CDC) project, mobile telehealth clinic vans will be stationed at libraries throughout the community for public health campaigns and will be used to deliver telehealth services into the communities on each island. This is part of an overall digital and health equity project that will enable libraries to serve as telehealth access points, by providing places for patients and families to access broadband, computers and support from digital navigators in the libraries as part of the American Rescue Plan Act of 2021 [6]. This is a joint project between the Hawai'i Department of Health, Hawai'i State Libraries and the Pacific Basin Telehealth Resource Center.

Robotic ultrasound

Robotic ultrasound has been utilized in Europe and Canada and shows promise for use in Hawai'i and other remote areas. Following an initiative to close the healthcare disparity gap associated with increased maternal and

newborn morbidity and mortality in Indigenous pregnant women in the region, obstetric tele-robotic ultrasound systems were implemented. They are currently used by two northern Canadian Saskatchewan communities to perform prenatal ultrasounds [7]. It has been recently tested successfully Trans-Atlantic between France and Rutgers cardiovascular teams using a 4G network [8]. It is approved by the Food and Drug Administration and the trans-oceanic connection shows promise for Hawai'i inter-island ultrasonography.

Review of the literature

The last decade has established in literature that healthcare disparity is present and telehealth is a tool for providers and patients to close health care gaps. The current review of literature for telehealth in pregnancy care is shown in Table 1.

National guidelines recommend 12–14 prenatal visits [9]. This was first established in 1930 with the aim to observe and intervene in pregnancy and did not provide patient-centered services driven by assessment of patient needs. Although prenatal care services are evidence-based, the COVID-19 pandemic and recent studies on flexible prenatal care show that patients do not need to be in-person to receive appropriate maternity services [10, 11]. Telehealth has emerged as a promising care option for patients needing flexibility. A few early trials utilizing virtual care and remote maternal and fetal monitoring have shown positive maternal and fetal outcomes with overall equivalent or improved patient satisfaction.

The American College of Obstetrics and Gynecology (ACOG) recommended a needs assessment prior to implementation and recommended telehealth also known as telemedicine to “enhance care” and not replace the standard of care [12]. Since the COVID-19 pandemic, telehealth has been increasingly utilized, while the evaluation of prenatal care visit format, home medical device use, patient satisfaction, and barriers to telehealth use is ongoing.

Obstetric outcomes

Several studies prior to the COVID-19 pandemic showed similar perinatal outcomes compared with traditional care without compromising the patient-physician relationship. The majority of these studies examine the use of telehealth virtual visits and other than a home-blood pressure cuff or blood glucose monitor, no other medical devices. A cohort study in 2016 analyzed maternal and

neonatal outcomes in 117 patients who chose a hybrid model of nine in-person prenatal visits and five virtual prenatal visits to 941 women who received 12 in-person visits. There were no significant differences in rates of cesarean birth, preterm birth, neonatal intensive care unit admissions, or birth weight. Despite a higher rate of preeclampsia in the virtual visit cohort, the above outcomes were not significantly different [13].

Likewise, in February 2020 a systematic review of Clinical Trials, Cochrane review, and medical literature database concluded that telehealth reduced in office-visits for patients requiring blood pressure or glucose monitoring without a change in maternal and fetal outcomes [14]. One study noted by the systematic review found reductions in diagnosed preeclampsia among women with gestational hypertension. Though two subsequent large randomized control trials (RCTs) in England published following the systematic review showed no significant reduction in preeclampsia diagnosis and no improvement in control of chronic hypertension in pregnancy [15, 16]. Nevertheless, the RCTs and systematic review both found that home blood pressure monitoring via telehealth did not incur an increase in maternal or neonatal morbidity or mortality, and few adverse events were noted [14–16].

The same 2020 systematic review concluded that telehealth use was associated with improved some obstetric outcomes including perinatal smoking cessation, increase in breastfeeding rate, earlier access to medical abortion services, and schedule optimization for high-risk obstetric patients requiring multiple appointments. Telehealthcare was effective for compliance with oral and injectable contraception methods. Medication abortion services had similar clinical outcomes compared with in-person care and improved access to early abortion. Addressing gynecologic needs was noted to be improved earlier notification of sexually transmitted infections via telehealth notifications and app-based urinary incontinence bladder training [14].

Antenatal testing

Remote ultrasound reading by an MFM has been shown to improve diagnostic accuracy when an in-person MFM specialist is not available. The potential for missed diagnoses was 34.5% in one recent study where MFM-trained sonographers, general OBGYNs and general practitioners all called the scan “normal.” There were significant differences in the rate of the potentially missed diagnoses by organ system, with the highest rate for cardiac anomalies [17]. In a study of remote fetal monitoring

Table 1: Review of literature for telehealth in pregnancy care.

Study	Design	Sample size and setting	Primary outcome	Secondary outcomes
Obstetric outcomes				
Pflugeisen, McCarren, et al. [13]	Cohort study	- Virtual: 9 in-person/5 virtual visits (n=117 participants). - In-person: 12 in-person v (n=941 participants). - All pregnancies low-risk.	No significant differences in cesarean section, preterm birth, NICU stay and birth weight between virtual and in-person cohorts.	Virtual: two times as likely to be partnered (p=0.03), not enrolled in government aid (p=0.01) an seven times more likely to have been pregnant before enrollment (p>0.001).
DeNicola, Grossman, et al. [14]	Systematic review	- Two high-risk questions: 7 RCTs, 1 non-RCT on telephone glucose monitoring 2 RCTs, 1 retrospective cohort study blood pressure remote monitoring. - Low risk questions: Smoking, breast feeding, and vaccines (19 studies)	- No significant differences in maternal or neonatal morbidity and mortality using blood pressure monitoring. - Blood glucose remote monitoring may have reduced macrosomia rate in gestational diabetes. - Recommended future well-designed studies on these high-risk topics.	Telehealth increased perinatal smoking cessation, breast-feeding rates, access to medical abortion services, schedule optimization for high-risk patients, and STI treatment.
Antenatal testing				
Kern-Goldberger, Haeri, et al. [17]	Cross-sectional study	11 private practices with ultrasounds read by sonographers and remotely by MFM providers. - Sonographers trained under standardized protocol. (n=6,403 ultrasounds in 6-month period).	- Sonographer anomaly detection rate of 3.2%. 4.8% had a fetal anomaly when remotely read by and MFM. - Rate 1.7% of missed diagnoses representing 34.5% of all MFM-diagnosed anomalies	- Potential missed diagnoses varied significantly by type of ultrasound (p<0.01). - Rate of the potential missed diagnoses differed and was highest rate for cardiac anomalies.
Butler Tobah, LeBlanc, et al. [18]	Single-center randomized control trial	- Adaption of Mayo clinic OB nest for hybrid group: 8 in-person visits/6 virtual visits (n=150) - Traditional care group 12 in-person visits (n=150). - Prenatal maternal stress validated scale score.	- No statistical differences in adherence to ACOG guidelines between groups. - No statistical significance in perceived quality of care between two groups.	- Pregnancy-related stress lower in the hybrid group at 14 weeks (hybrid=0.32 vs. traditional=0.41, p<0.01) and 36 weeks (hybrid=0.34 vs. traditional=0.40, (p<0.030). - Nursing time was higher (hybrid=171.2 min vs. usual care=108.2 min, 95% CI, 48.7–77.4). - Increased satisfaction with care (hybrid=93.9% vs. traditional=79%, p<0.01.
Patient satisfaction				
Peahl, Novara, et al. [10]	Descriptive survey-based.	Survey of patients (n=322) 90% response rate.	Majority of patients reported comfort with home monitoring skills: Measuring weight (91%), blood pressure (82%), and fetal heart tones (68%).	- Median=10 prenatal visits of patients desiring <12 visits. (63% of total patients) - Caucasian or privately insured were more likely to prefer fewer visits. 84% desired contact with the care team between visits. - Most desired two or more postpartum visits (91%), with the first visit within 3 weeks after discharge (81%).

Table 1: (continued)

Study	Design	Sample size and setting	Primary outcome	Secondary outcomes
Peahl, Powell, et al. [21]	Survey	- Single site evaluations of COVID-19 prenatal hybrid care model - Survey patients (n=1,690) with 15.0% response rate. - Survey providers (n=103) with 74.8% response rate.	92.2% of patients believed that blood pressure cuffs were important for virtual visits 77.5% patients and 83.1% providers reported satisfaction with the hybrid COVID-19 prenatal care model.	- Weekly total visit volume fell by 16.1% with introduction of hybrid care model - Weekly proportion of virtually conducted visits increased from 10.8 to 43.3%, with no-show rate remaining stable. - Most patients, 68.8% and providers, 96.1% reported virtual visits improved access to care. 53.5% patients and 62.1% providers believed virtual visits were safe. - Patients mostly white and insured.
Fryer, Delgado, et al. [22]	Survey	Standardized obstetric protocol (Mayo clinic OB nest model) was developed that combined eight in-person visits with six virtual nursing visits, an asynchronous online portal.	Participants in OB nest had higher patient satisfaction and lower stress compared to standard care.	N/A

Implementation challenges

Pagalday-Olivares, Sjöqvist, et al. [23]	Descriptive	- Triangulated research methods conducted to gather data on Kpando Municipality, Ghana. - Telehealth implementation analyzed with Drury's 5C eHealth model.	- Factors that influence maternal care outcomes: Financial dependence of women, a decision-making process based on previous experiences and traditional beliefs, competitiveness between facilities, organizational loopholes, lack of equipment, and geography. - Telehealth solutions have potential to reduce maternal health care delays.	Factors that challenge telehealth implementation include poverty, cultural beliefs, organizational issues, connectivity, and lack of human resources.
Noordam, Kuepper et al. [24]	Literature review	Analysis of potential of mobile phones to improve maternal health services in low and middle-income countries via search scientific and gray literature. Applications requiring internet connection were excluded.	Use of community volunteer mobile phones has potential to mitigate low internet and broadband penetration in rural areas.	Use of community volunteer mobile phone shown to increase skilled birth attendance.
Lund, Rasch, et al. [25]	Clustered, randomized controlled trial	- Primary health care facilities (n=24) in Zanzibar randomized to phone intervention or standard care. - Pregnant patients attending health care facilities (n=2,550) were included from first antenatal care visit to 42 days after delivery.	- Perinatal mortality rate was lower in the intervention group (19 per 1,000 births) than in the control clusters (36 per 1,000 births). - Reduction in perinatal mortality with OR of 0.50 (95% CI 0.27–0.93).	Mobile phone intervention is associated with increased rates of skilled birth attendance.

Table 1: (continued)

Study	Design	Sample size and setting	Primary outcome	Secondary outcomes
Waldrop, Cruz, et al. [26]	Survey	- Provider surveys (n=328) of society for maternal-fetal medicine members in December 2020, amid the Covid-19 pandemic. - More than half (52%) of respondents reported practicing in a university hospital setting.	- No difference observed in telehealth (live video) user status in the patients covered by Medicaid. - No difference in provider-reported barriers to telehealth usage by percentage of publicly insured patients in their practice.	40% of respondents, regardless of insurance type, reported reimbursement and insurance coverage as a barrier to telehealth. 50% of the respondents across payer mix reported patient access to internet or data plans as a barrier to telehealth implementation.
Ukoha, Davis, et al. [27]	Commentary	Presenting considerations for health care entities to promote equitable implementation of telemedicine.	- Waivers for reimbursement vary by state. - Payment can be less for FQHCs for in-person compared to telehealth encounters. - Issuing standardized equipment can be difficult to trouble-shoot for providers.	- Health care practitioner attitudes and perceptions may result in differential and inequitable implementation of telemedicine. - Safety net health systems and community health centers have lagged in offering telemedicine. - Barriers are: absence of technology or reliable internet coverage, low health and digital literacy, and being a non-English speaker.
Pandemic contributions				
Almuslin, AlDossary, et al. [28]	Literature review	Computerized search of PubMed, Cumulative index of nursing and allied health literature (CINAHL) databases for published work before October 2020. (n=25)	More than half of the 15 protocols (n=9; 60%) recommended fewer than seven face-to-face visits.	- Vaccines, ultrasound, and physical exams and genetic screening, and lab test were performed in person. - The majority of fundal heights 75% (n=4 studies) and heart tones 80% (n=5) were performed in person. - Barriers included lack of access to high-speed internet and hardware, and inaccessibility to patients.
Kern-Goldberger, srinivas, et al. [29]	Narrative and literature review	Review by experts in the field on role of telehealth for pregnancy management in the COVID-19 pandemic and barriers, challenges, and strategies for obstetric telemedicine.	Several templates for obstetric care have been published since 2020 by various obstetric health care groups across the globe reflecting their experience with telehealth.	Telehealth interventions were adopted to provide care to patients requiring MFM care during COVID-19.
Peahl, smith, and Moniz [11]	Narrative review	- Historical review of care and proposal of hybrid telehealth and in-person system at a single institution. - Average risk pregnancies	Hybrid model proposed for flexible, virtual care of average risk pregnancies.	- Telehealth may be advantageous in addressing health disparities in maternal care access and outcomes. - Barriers include unstable internet connections.
Vora, Hardisty, et al. [30]	Site-evaluation	Analysis of workflow at UNC Chapel Hill to implement rapid remote prenatal genetics services in the setting of a global pandemic.	Week 1 of study had 91 telehealth visits. Week 2 had 172 telehealth visits. Week 3 had 269 telehealth visits.	N/A

Table 1: (continued)

Study	Design	Sample size and setting	Primary outcome	Secondary outcomes
Jeganathan, Prasannan, et al. [31]	Survey and retrospective analysis	- Large urban and suburban health care system. Survey of high-risk obstetrical patients who received a telehealth visit between 03/01/2020 and 05/30/2020 (n=91). - Survey of providers participating in same visits (n=33). - Review of visit rates, high-risk prenatal care appointments, diabetes mellitus education sessions, and genetic counseling and MFM consultations prior to telehealth implementation in 2020.	86.9% of patients satisfied with the telehealth care. 73.8% of patients desired a combination of in-person and telehealth. - Providers preferred in-person to telehealth (56 vs. 23%, p=0.024). 90.9% of providers stated telehealth improved care access.	- Telehealth visits vs. in-person visits in 2020, significantly lower rate of patient-canceled appointments (3.82 vs. 5.44%, p=0.021) and same-day cancellations (0.60 vs. 1.65%, p=0.002). - With implementation of telehealth, lower rate of no-show appointments (8.49 vs. 4.61%, p<0.001), patient-canceled appointments (7.06 vs. 4.96%, p<0.001), and patient same-day cancellations (2.30 vs. 1.35%, p<0.001) - Barrier: Implementation of telehealth decreased adherence to the appointment schedule.

in low-risk pregnancies utilizing OB Nest, a Mayo Clinic protocol developed with phone-application communication of fundal height, blood pressure and hand-held doppler, adherence to ACOG's guidelines for prenatal services was similar in both groups [18]. Maternal and fetal outcomes were similar between groups. Total reported nursing time was higher in the OB Nest group.

Patient satisfaction

The 2016 cohort study results mentioned prior noted hybrid in-person/virtual patients' satisfaction was significantly higher but had a non-significant absolute difference between their rating of virtual compared to in-person visits [19]. In a cross-section study of 332 patients, a 90% response rate found that most patients reported comfort with home monitoring skills in the categories of measuring weight, taking blood pressure, and monitoring fetal heart tones. It should be noted that fetal heart tones were the lowest at 68% of survey respondents who felt comfortable taking their own fetal heart tones [10].

Home monitoring devices, such as blood pressure cuffs and handheld Dopplers have been controversial given concern for overutilization of acute care if erroneous measurements are taken [20]. Despite this, survey studies have suggested that these devices may increase both patient and provider comfort and satisfaction with virtual care [10, 21]. In a study conducted by researchers at

the University of South Florida in 2020, a standardized obstetric protocol for pregnant patients was developed using a virtual care schedule model (OB Nest) to reduce in-person visits and incorporate telehealth into the schedule of prenatal care. Patients were provided with blood pressure cuffs and fetal dopplers, and followed a schedule consisting of a combined virtual and prenatal care protocol combining eight in-person visits with six virtual nursing visits, an asynchronous online portal for questions and education, and an online community moderated by nurses. Compared to the control group, participants in the OB Nest group had higher patient satisfaction and lower stress levels [22].

Challenges to implementation of telehealth

Lack of access or digital literacy with smart-phone and computer technology is can limit access to modern healthcare services. To promote digital equity and reduce delays in maternal healthcare in rural communities of Ghana, telehealth solutions were implemented to reduce delays in seeking care and discovered the potential to reduce maternal mortality as well as cultural and financial barriers to utilizing telehealth [23]. In order to mitigate low internet and broadband penetration in rural areas, some studies suggested relying on the use of community volunteer mobile phones, which incidentally have been shown to increase skilled birth attendance

[24, 25]. In order to minimize the burden of cost, mobile financial services were provided to pregnant women to help them access financial services for maternal health-care [23]. A United States-based study compared barriers encountered by MFM practices in the majority Medicaid and majority non-Medicaid insured patients [26]. Both groups received care at University-based practices and showed no significant differences in the rate of barriers faced between the differing types of insured patients. The two most common barriers faced by both groups were patient access to the internet or data plans and “soft-ware/hardware usability” [26].

Additional challenges have been noted. Waivers for reimbursement for telehealth may vary by state, as the extension was not granted following the initial phase of the COVID-19 pandemic. Payment can be less for FQHCs for in-person compared to telehealth encounters and issuing standardized equipment, a medical device or a pharmacy item and training a patient on how to use a device can be difficult to trouble-shoot initially for providers [27].

COVID-19 pandemic contributions

Since the advent of the COVID-19 pandemic, current telehealth literature has increased substantially due to the necessity of isolation. Studies noted benefits to patients and providers as well as some barriers to telehealth access. A recent review of 25 published reports aimed to analyze how obstetric care systems responded to the COVID-19 pandemic concluded that protocols developed replaced some in-person visits with telehealth visits when no testing was required [28]. Common reported benefits were minimizing exposure and the continuity to provide safe care. Lack of access to high-speed internet and hardware and inaccessibility to patients were the most reported barriers [28].

Several expert opinions and templates for obstetric care have been published by various obstetric health care groups across the globe reflecting their experience with telehealth during 2020 and onward [29]. Examples include a group at the University of Michigan that proposed a Michigan Plan for Appropriate Tailored Health Care in Pregnancy (MiPATH), a constellation of expert recommendations for more flexible prenatal care for patients with average risk with 4 in-person visits, 1 ultrasound visit, and 4 virtual visits (the 4-1-4 prenatal plan) [11].

Pregnancies requiring genetic counseling were shown to overall adapt to the telehealth format. The University of North Carolina at Chapel Hill described its workflow well for transitioning genetics consults to telemedicine during the pandemic [30]. Their program decreased in-person resources to be mostly utilized for ultrasound and prenatal diagnostic procedures while providing safe and effective patient care for genetic counseling and psychosocial support after a difficult diagnosis with virtual visits with genetic counselors [30]. Telehealth appointments for low-risk patients or patients with only specific needs such as genetic counseling or preconception counseling have become more commonplace since 2020.

High-risk pregnant patients who require an MFM's care, still faced the same risk of exposure in the era of the early pandemic as low-risk patients but had even more complex medical and psychosocial needs. Thus the medical community was driven to adapt. Columbia University Irving Medical Center's report of this time period shows well-outlined, evidence-based protocols for specific high-risk conditions including patients with increased risk of still-birth, cardiovascular conditions, hypertension, pregestational diabetes and fetal anomalies. These high-risk patients were provided services and coordination through a hybrid telehealth format [29]. Antenatal testing such as non-stress tests and ultrasounds were still performed in person and the report concludes that telehealth virtual visits did not fully replace in-person prenatal care, but offered a means of reducing potential exposure to COVID-19 while providing consolidated in-person services. For patients requiring care by a MFM, one recent study showed patients' preference for telemedicine when available though the implementation actually decreased patient adherence to the appointment schedule [31]. ACOG recommends that each region assesses and decides the number of inpatient and telehealth visits appropriate for their unique population [32].

Consensus on some aspects of telehealth still remain to be widely established such as ensuring patients' internet or data-plan access, patient comfort with home monitoring devices, and provider reimbursement for telehealth visits and remote monitoring systems. Current literature is promising that a more patient-centered telehealth prenatal format can benefit the accuracy of care, increase patient satisfaction and reduce the need for in-person visits. Community/patient needs assessment, adherence to evidence-based guidelines and strict protocols are commonly cited by experts in the field as

important components for telehealth implementation. Evaluation of telehealth use in remote and global regions with successful telehealth services may inform better practices for telehealth in remote areas worldwide.

Conclusions

The results of a state-wide maternal telehealth needs assessment demonstrated a strong need for the creation of an integrated maternal telehealth system for Hawai'i as a public utility. Our experience highlights the need for the State of Hawai'i to implement maternal telehealth services to improve access to prenatal and postpartum services in low resource communities. The COVID-19 pandemic precipitated the rapid adoption of MFM video consultation to neighboring islands. Federal, State, and private funds were obtained to provide remote patient monitoring, tele-ultrasound infrastructure, coordinated care between provider, MFM specialist, and patient. Software storing, reporting, and the ability to share ultrasound images across the Hawai'ian islands were also obtained. These implementations demonstrate improvements in providing access to maternal health care, quality, and affordability. As revealed by the COVID-19 pandemic, the benefits of telehealth extend beyond OB/GYN to other medical specialties, and may help to improve general healthcare access in rural, low resource, and remote communities. Important future directions include an evaluation of cost-efficacy and areas of improvement of these pilot telehealth programs. It will also be important to demonstrate how pregnant patients can be more efficiently triaged using the increased access to telehealth resources in their local communities to higher levels of care.

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