ARTICLE

Remote monitoring for neonates requiring continued nasogastric tube feeding: implementation, patient characteristics, and early outcomes

Christina Fisher[1,3], Meredith Haag[1], Angela Douglas[1], Arnette Kayhani[2] and Jamie B. Warren[1]✉

OBJECTIVE: Our neonatal intensive care unit utilizes remote patient monitoring to facilitate hospital discharge with nasogastric tube (NGT) feeds. Program implementation, patient characteristics, and initial outcomes are described.
STUDY DESIGN: Data was collected prospectively in this implementation study. Descriptive statistics define weight gain, number of NGT feed days, number of days on monitoring, and physician time spent. Patient characteristics, readmissions, and implementation details are described.
RESULTS: One-hundred and four babies consented to and completed data collection. Average weight gain on monitoring was 31.4 g/day (SD 10.2). Eighty-nine babies (85.6%) achieved full oral feeds while on the program, requiring a median 5 NGT feed days (IQR 2–13) and a median 15 days on monitoring (IQR 11–27). Average physician time spent was 9.1 min per day (SD 3.7). Six babies (5.8%) had unscheduled readmissions while on the program.
CONCLUSION: Remote monitoring programs can facilitate discharge for babies with continued NGT needs.

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INTRODUCTION

Generally accepted neonatal intensive care unit (NICU) discharge criteria include cardiorespiratory stability, maintenance of appropriate body temperature, and ability to eat everything needed for growth by mouth [1]. Inadequate oral feeding (IOF) is commonly the remaining barrier to NICU discharge; in over 3300 moderately preterm babies who remained hospitalized at 36 weeks post-menstrual age (PMA), 37% claimed IOF as their remaining hospital problem [2]. Home nasogastric tube (NGT) feeding provides the opportunity for earlier NICU discharge. Programs that utilize home nursing visits to monitor babies with home NGT feeds have been described in Europe [3–9]. Home NGT programs in the United States have typically provided follow-up in ambulatory settings [10–15].

Remote patient monitoring (RPM) is a form of telemedicine that uses digital health technologies in the home to allow patients to collect and transmit data to their healthcare team, typically supplemented with phone or video communication [16]. RPM offers the opportunity to provide care in the home that has traditionally been provided only in the hospital. Neonatal RPM programs have been described in Denmark [17–19] and Sweden [20, 21] as an enhancement to home NGT feeding programs. More recently, two separate NICU RPM programs have been described in the United States that facilitate early discharge with NGT feeding for babies with IOF [22, 23]. In May 2019, the Oregon Health & Science University Doernbecher Children's Hospital (DCH) NICU started an RPM program called Growing @ Home (G@H) for babies who remained admitted to the NICU with IOF alone. The aim of this study is to describe the process of program implementation, report on initial patient characteristics and outcomes, and discuss program feasibility and sustainability.

METHODS

This trial was designed as an implementation study that prospectively followed a cohort of patients discharged on G@H, allowing evaluation of patient characteristics and outcomes.

Setting

The DCH NICU is a 46-bed, level IV unit within Oregon Health & Science University, Oregon's only academic medical center, in Portland, Oregon, USA. The NICU has pod-style rooms that hold four to eight babies; parent rooming-in is not possible. Of approximately 700 annual admissions, one-third are out-born. Babies in this G@H cohort were discharged from the DCH NICU between May 2019 and April 2022.

Platform

The G@H RPM platform is provided by Locus Health©, a remote care management software company based in Charlottesville, Virginia, USA. At program implementation, families were loaned a Wi-Fi capable and pre-paid cellular data plan-equipped (if Wi-Fi was unavailable) tablet enabled by the Locus platform with a patient-facing application utilized for data entry. Beginning in 2022, families could download the patient-facing

[1]Department of Pediatrics, Oregon Health & Science University School of Medicine, Doernbecher Children's Hospital, Portland, OR, USA. [2]Oregon Health & Science University, Portland, OR, USA. [3]Present address: Department of Pediatrics, University of Colorado School of Medicine, Children's Hospital Colorado, Aurora, CO, USA.
✉email: warrenja@ohsu.edu

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application to a personal device rather than using the loaned tablet, if preferred. Data entered by the family is simultaneously uploaded to clinical dashboards available to the care team. If the data is entered into the application outside of a cellular data service or Wi-Fi enabled area, it will upload automatically when the device moves into one of these locations. The G@H care team visualizes the data on a secure, HIPAA-compliant and password-protected website accessible by computer or personal device. The G@H team worked directly with the software company to determine content of the application and clinical dashboards prior to program implementation. During remote monitoring, the family is required to input a daily weight (kg) and volume (mL) taken via NGT, bottle, or at breast for each feed. Parents have the opportunity to upload pictures and record free-text concerns or questions. The platform is available in English and Spanish.

Eligibility

Babies become eligible for G@H when the following are achieved: (1) PMA ≥ 35 weeks, (2) weight ≥ 2 kg, (3) ability to take a minimum of 30% of daily feeds by mouth, (4) consistent weight gain on a stable feeding regimen, (5) >5 days of cardiorespiratory stability without apnea or bradycardia requiring stimulation for recovery, and (6) thermoregulation. These discharge criteria are similar to those for other home NGT feeding programs [5, 6, 8, 10, 12, 13, 22]. Families must demonstrate involvement in care during the NICU stay, have a stable method of telephone communication, and agree to all aspects of home NGT feeding (including replacement of the NGT if necessary). A multidisciplinary group that includes the medical team, social work, speech language pathology, dietician, and case management participate in making decisions on patient eligibility. Exclusions include inability of the baby to safely feed by mouth, unwillingness or inability of family to manage NGT feeds in the home, and primary language other than English or Spanish.

Family education/equipment

In addition to routine NICU discharge education provided by nursing staff and medical providers, the NICU case manager teaches families to use the RPM application and an infant scale. The Medela (McHenry, Illinois, USA) BabyWeigh^{TM} II scale is provided for families who are feeding at breast to facilitate accurate documentation of intake at breast (using pre- and post-breastfeeding weight) as well as daily weight. Due to having a limited number of breastfeeding scales, families who are exclusively bottle-feeding are provided with a scale that weighs to the 0.01 kg for daily weight measurement. NGT placement technique is taught by bedside nurses, a routine practice in the DCH NICU. Parents must demonstrate the ability to place and verify placement of the NGT on at least two occasions; they are taught to aspirate gastric contents to confirm placement. Families meet with a home health vendor regarding home feeding equipment (provided by insurance), including pH testing strips for NGT placement verification. If they are unsure of NGT placement, families are counseled to remove and replace the NGT, or call the NICU or their primary care provider (PCP). Requiring babies to feed at least 30% by mouth removes the emergency aspect of NGT replacement. Families are additionally educated that the RPM application is not an emergency form of communication; if urgent questions or concerns arise, parents are advised to call their baby's PCP or to seek more urgent care as needed. Assistance is available 24 h a day by calling the DCH NICU.

G@H workflow

PCPs are informed of the G@H program prior to NICU discharge and routine NICU discharge follow-up with the PCP is scheduled. Starting the day after discharge, a NICU physician calls the family for "daily rounds," during which RPM data are reviewed, questions answered, and a plan is made for the following 24 h. The NICU physician then documents a progress note in the electronic health record. At the end of the calendar month (or at the time of discharge from G@H), the NICU physician bills for the time spent on RPM for the entire month, using billing codes 99457 and 99458. Most babies are followed by a speech language pathologist and a dietician within 2–3 weeks of discharge, either in person or virtually, and as needed thereafter. If at any time during the RPM process additional communication with the PCP is necessary (for example, if weaning from the NGT is not occurring as expected), the G@H physician communicates with the PCP by phone.

Transition to an ad lib feeding schedule occurs in the home as it does in the hospital. After the NGT is removed, babies are followed via RPM for a minimum of five days to ensure adequate intake, weight gain, and family comfort. After discharge from G@H, the NICU physician ends the episode of care through the RPM application, and parents return the scale to the NICU. If utilized, families mail the tablet device to Locus Health in a postage-paid shipping box. The G@H physician contacts the PCP either over the phone or electronically to notify them that the baby has been discharged from the program.

Data collection and analysis

For study purposes, the following data points were recorded for each baby. At the time of NICU discharge, sex, home zip code, gestational age (GA) at birth, birth weight, PMA at NICU discharge, weight at NICU discharge, and primary and secondary diagnoses were recorded. Upon discharge from G@H, G@H discharge weight, number of NGT days, number of total days on RPM, readmissions, and time spent per day by the NICU physician on RPM activities were recorded. Primary outcomes of program implementation were descriptive: weight gain (g/day) on RPM, number of days with home NGT feeds, number of days on RPM, number of readmissions, and physician time spent on RPM activities. Microsoft Excel 2016 was used for descriptive statistics including means with standard deviations (SD) and medians with interquartile ranges (IQR). Means were calculated for GAs, weights, and physician time due to the normal distribution of data. Medians were calculated for days of home NGT feeds and days on RPM due to the presence of outliers in the data set.

The study was approved by the Institutional Review Board at Oregon Health & Science University (#19657). Written informed consent for data collection was obtained prior to discharge from the DCH NICU.

RESULTS

Between May 2019 and April 2022, 109 babies were enrolled in and discharged from G@H. Of these, 104 parents provided consent for and completed data collection while on the RPM program. Ninety-two babies (88.4%) were born prematurely (<37 weeks' gestation); 43 babies (41.3%) were female. Thirty-two babies (30.8%) had additional significant diagnoses beyond IOF and/or prematurity (Table 1). All families in this cohort were English speaking.

The mean GA at birth for this 104-patient cohort was 32w5d (range: 24w0d to 40w4d). Mean and standard deviation (SD) for GA at birth, birth weight, PMA at NICU discharge, and NICU discharge weight for all babies and for gestational age categories are shown in Table 2. The average weight gain per day while on RPM for all 104 babies was 31.4 g/day (SD 10.2 g/day).

Eighty-nine babies (85.6%) achieved full oral feedings during the G@H program. The median and IQR for NGT feed days and

Table 1. Significant diagnoses in addition to IOF and prematurity in this G@H cohort (40 additional diagnoses in 32 babies).

Bronchopulmonary dysplasia ($n = 10$)[a]
Surgical diagnoses ($n = 7$)[b]
Genetic differences ($n = 7$)
Neurological complications ($n = 7$)[c]
Kidney disease ($n = 3$)[d]
Severe intrauterine growth restriction ($n = 3$)
Intrauterine drug exposure ($n = 2$)
Severe retinopathy of prematurity, Stage 3 or higher ($n = 1$)

[a]defined as positive pressure ventilation or oxygen requirement at 36 weeks' PMA.
[b]including duodenal atresia, Hirschprung's disease, congenital diaphragmatic hernia, laryngomalacia, myelomeningocele, Tetralogy of Fallot.
[c]including intraventricular hemorrhage grade III/IV, periventricular leukomalacia, cerebellar hemorrhage, neonatal encephalopathy.
[d]including single kidney, severe vesicoureteral reflux, posterior urethral valves.

Table 2. Characteristics of G@H patients at NICU discharge.

	n (%)	Mean GA at birth, (SD)	Mean birth weight (g), (SD)	Mean PMA at NICU discharge, (SD)	Mean NICU discharge weight (g), (SD)
All patients	104	32w5d (3w4d)	2011 (806)	38w5d (3w0d)	3059 (733)
<29 weeks' GA at birth	14 (13.5)	26w5d (1w4d)	1004 (288)	41w3d (3w4d)	3790 (647)
29–33 weeks' GA at birth	49 (47.1)	31w4d (1w4d)	1741 (487)	38w0d (2w3d)	2955 (648)
34–36 weeks' GA at birth	29 (27.9)	34w5d (0w5d)	2510 (679)	37w0d (1w2d)	2708 (624)
37–40 weeks' GA at birth	12 (11.5)	38w4d (1w2d)	3079 (475)	42w1d (2w2d)	3520 (567)

days on RPM for these 89 babies in total and by GA category are shown in Table 3.

Fifteen babies (14.4%) continued to require tube feeding at discharge from G@H. These babies spent a median 78 days (IQR 48–94.5 days) on RPM. Eleven (73.3%) of these babies had diagnoses in addition to IOF and prematurity, including bronchopulmonary dysplasia (BPD, defined as positive pressure ventilation or oxygen requirement at 36 weeks' PMA; $n = 5$), severe (grade III or IV) intraventricular hemorrhage (sIVH, $n = 3$), genetic differences ($n = 3$), neonatal encephalopathy ($n = 1$), and severe intrauterine growth restriction ($n = 1$). Feeding outcomes for these 15 babies ranged from gastrotomy tube placement during the RPM episode to continued NGT feeds managed by the PCP and ambulatory feeding specialists with eventual achievement of full oral feeds or requirement for gastrostomy tube placement.

During their time on RPM, 10 babies were readmitted to the hospital a total of 12 times. Six of these readmissions were unscheduled; one occurred in a baby on full oral feeds and just prior to RPM discharge. For the remaining five babies who required unscheduled readmission, four occurred in babies born at a gestation less than 28 weeks, and all five babies had significant diagnoses other than IOF (including BPD, sIVH, and/or genetic differences). Reasons for unscheduled readmission included brief resolved unexplained event ($n = 2$), emesis ($n = 1$), apnea ($n = 1$), respiratory distress ($n = 1$), and fever ($n = 1$). Malposition of the NGT was not implicated as a cause of these events for any of the babies. Reasons for scheduled admission were procedural: cyst removal, cardiac catheterization, retinopathy of prematurity surgery, and gastrostomy tube placement.

The average time per day spent on RPM for the NICU physician (including data review, discussion with family, and documentation) for all 104 babies was 9.1 min per day (SD 3.7 min per day). The average time spent for babies who achieved full oral feedings while on RPM was 9.0 min per day (SD 3.8 min per day). Therefore, for babies who achieved full oral feeding during the RPM episode (median 15 days), the NICU provider spent 2 h and 15 min on the entire RPM episode. The average time spent for babies who did not achieve full oral feedings while on RPM was 9.7 min per day (SD 2.8 min per day). NICU provider time spent for these RPM episodes (median 78 days) was longer—on average 12 h and 37 min for the entire RPM episode.

DISCUSSION

We describe the implementation of an early discharge program that utilizes RPM to support babies in the home while they continue to gain oral feeding skills. Among babies who achieved full oral feeding during the program, enrollment in G@H resulted in a median 5 days of home NGT feeds and 15 days on RPM. For all G@H babies, average weight gain during RPM was just over 31 g/day. We found RPM to be a feasible way to care for babies with IOF as the only barrier to NICU discharge.

Safety results for our program are comparable to others [3–9]. Unscheduled admission rates between 5% and 12% have been reported by other home NGT feeding programs [5, 6, 9, 15]. Six babies (5.8%) in our cohort required unscheduled readmission to the hospital during the RPM period, one of whom was readmitted after the NGT had been removed. NGT placement or positioning was not noted to be a concern at the time of readmission for any of the other five readmitted babies. Lundberg et al found birth at <28 weeks' gestation to be a significant risk factor for readmission in their program [5]. Four of the six babies (66.7%) with unscheduled readmissions in our cohort were born at less than 28 weeks' gestation. Additionally, all five of the babies readmitted while the NGT was still in place experienced other significant diagnoses, including BPD, sIVH, and/or genetic differences. While the study of NICU readmissions is difficult [24], Lagatta and

Table 3. NGT feed days and duration of RPM episode for patients who achieved full oral feeds during G@H.

	Median NGT feed days, (IQR)	Median days on RPM, (IQR)
Patients who achieved full oral feeds during G@H episode ($n = 89$)	5 (2–13)	15 (11–27)
<29 weeks' GA at birth ($n = 9$)	8 (6–15)	29 (14–33)
29–33 weeks' GA at birth ($n = 41$)	5 (2–19)	17 (11–30)
34–36 weeks' GA at birth ($n = 28$)	6 (2–9.3)	15 (11.8–20.3)
37–40 weeks' GA at birth ($n = 11$)	3 (2.5–4.5)	13 (11–17)

colleagues found that babies discharged with home NGT feeds in their program did not have significantly more emergency department use or unscheduled admissions compared to babies discharged from the NICU on full oral feeds [10]. While our data is preliminary, we are seeing early evidence that readmissions while on RPM may be more likely in babies born at earlier gestations and/or with additional diagnoses or morbidities of prematurity. This may help inform other NICUs in the development of their RPM programs.

At the outset of the program, we believed that the moderately preterm population would be the primary utilizer of G@H, and 47.1% of the babies in our cohort were born between 29 and 33 weeks. However, the a priori definition of discharge criteria allowed our team to determine eligibility unrelated to GA at birth. We have discharged a larger number of late preterm and term babies (27.9% and 11.5% of our G@H population, respectively) than we originally expected. Not unexpectedly, extremely preterm babies (13.5% of our G@H population) made up an overall smaller percentage of our cohort due to the frequent presence of continued hospital problems in addition to IOF that precluded participation in G@H. As seen in Table 1, use of the discharge criteria led to broad participation, even in infants with additional medical conditions.

For the 89 babies included who achieved full oral feeds during the RPM episode, the median number of NGT feed days was 5 (IQR 2–13 days). This is a shorter duration than described by van Kampen, et al (median 9 days) [6], Mago-Shah, et al (median 8 days after outliers were excluded) [12], White, et al (median 13.5 days) [14], and Lagatta, et al (median 29 days) [10]. However, our findings are similar to the duration described by Vergales, et al (mean 5.9 days), which has similar discharge criteria and follow-up methodologies as our program [22]. Our duration may have been shorter due to delays in discharge from when true discharge criteria were met. Discharge on G@H is dependent on both program personnel and family comfort with NGT feeding and data recording. It is also possible that our babies have shorter NGT duration because of efficiency in NGT removal, made possible due to daily contact with families. The median five days of having NGT feeds in the home as opposed to remaining in the hospital for these 89 babies is meaningful, not only for the decrease in utilization of healthcare resources, but also in the lives of the families that have endured the stressors of a NICU hospitalization.

G@H was originally envisioned to facilitate discharge of the routine, moderately preterm baby during the "feed and grow" stages of the hospitalization. We have discovered a small but important subset of babies that can utilize G@H to provide a prolonged amount of non-hospital time to either achieve full oral feeds or lead to the decision to have a surgical gastrostomy tube placed. Fifteen babies (14.4%) in this cohort continued to require tube feeds after the RPM episode. The median duration of RPM for this subset was 78 days (IQR 48–94.5 days); this variability is due mainly to not having a programmatic plan of how to manage these babies at G@H implementation. With experience, we are better understating potential risk factors for not achieving full oral feeds during RPM. Of the 15 babies in the cohort who fell into this category, 11 (73.3%) had additional significant diagnoses listed in Table 1, as opposed to 21 (23.6%) of the 89 babies who achieved full oral feeds. Twelve of the 15 (80%) babies who did not achieve full oral feeds by the time of G@H discharge were discharged from the NICU at a PMA of 40w0d or beyond, compared to 23 of the 89 (26%) babies who achieved full oral feeds. Based on this, we now counsel families on and plan for outpatient surgical consultation at around 48 weeks' PMA for babies with these risk factors, which can be canceled if full oral feeding is achieved. Decisions to move toward gastrostomy tube placement are multidisciplinary and include the G@H physician, occupational therapy, dietician, speech language pathologist, PCP, and family. In general, for babies who do not achieve full oral feeds while on G@H, the timing of transition off of the program is individualized and is a joint decision among family, feeding specialists, the NICU provider, and the PCP. Additionally, at around the 30-day time period on RPM, frequency of phone communication between the family and the G@H provider as well as frequency and content of data entry by the family is typically decreased based on family comfort and generally stable care plans.

The use of RPM as the main method of follow-up gives our program several strengths. The technology enables efficiency that is not possible with programs that rely on home or ambulatory visits. For the 85.6% of infants in our cohort who achieved full oral feeds, neonatal physicians averaged 2 h and 15 min of work per patient for the entire monitoring episode (compared to the daily examinations, rounding, documentation, and family discussion time that would have occurred if the baby had remained hospitalized). In contrast, programs that utilize home nursing visits describe more time spent on fewer visits (from 3.8 h on 4.8 home visits to 10.4 h on 5 house visits) [3, 6]. For infants in our cohort who did not achieve full oral feeds, the time spent by neonatal physicians averaged 12 h and 37 min per patient for the entire monitoring episode. As we refine the G@H program, we anticipate that consistent guidelines on the transition of patients who will require long term tube feeding support to full ambulatory follow-up with shorten this time. In general, the use of RPM saves an immeasurable amount of time for the entire NICU team, and increases capacity to care for babies who need critical care.

RPM facilitated discharge regardless of proximity to the hospital. Twenty-five of our patients (24%) lived greater than 60 miles from our hospital. Programs that rely on home or ambulatory visits for follow-up may have exclusion criteria based on distance from the hospital [8, 9]. Limitations in pediatric home health nursing, as are present in our state, can also limit discharge to more rural areas. With RPM, Wi-Fi or cellular data connection and telephone service is all that is needed to maintain contact with the healthcare team. We believe that the ability to send patients home regardless of proximity to the hospital makes our results more generalizable, and it allows for more equitable use of program resources.

Daily tracking and interaction with families provides several advantages. Frequent assessment of weight gain and oral feeding percentage allow us to make regular adjustments to feed volume and caloric concentration (leading to the average weight gain of 31.4 g per day in our cohort), and to determine when the NGT could be removed. Daily contact also fosters continuity and relationship-building that allowed for both assessment of family

coping and the ability to provide encouragement and support, such as for breastfeeding. We can also identify follow-up needs with neonatal feeding specialists, dieticians, or other pediatric specialists in a timely way.

The main limitation of this report is the lack of a comparator group, either in the form of a retrospective set of controls or a prospectively identified group of patients that qualified for G@H but remained in the NICU until full oral feedings were achieved. Since G@H was implemented as a new standard of care in the DCH NICU for those babies that qualified, prospective randomization to G@H or continued NICU care was not feasible. However, despite the lack of a comparator group, we believe that this description of program implementation can be helpful for other NICUs who may be interested in starting an RPM program.

The two main facilitators of implementation of G@H were funding and acceptability. Philanthropy was utilized to fund the initial build of the application and the RPM costs for the initial 100 G@H patients. While we continue to have a great amount of interest from donors to help to continue the program, we have also used the data and feedback from the initial four years of the program to report to hospital administration the benefits of G@H to babies, families, and strain on NICU resources. Additionally, from the beginning of the program, we have had great acceptance and support from all members of the NICU team in helping to make G@H a success. Specifically, physicians, advanced practice team members, nursing leadership, bedside nursing, social work, case management, speech language pathology, occupational therapy, and registered dieticians have all had active roles in promoting implementation and supporting the maintenance of the program. Continued feedback from families and from PCPs on the benefits of the program further support program maintenance.

As with any new program, we have had to adapt and evolve. With a goal of continuous improvement, we have refined the method of patient identification and timing of program introduction to families in the NICU. Working with the remote care management software company, we have made adjustments to the application as suggested by families, including addition of a post-partum depression questionnaire. We have also implemented the ability for families to utilize their personal devices to download the application, and have had the content of the application translated into Spanish. More recently, with the creation of billing codes for remote patient monitoring, our program has developed the workflows to bill for this service.

We continue to learn from G@H and discover how our care can be improved. Future avenues for improvement include development of more robust feeding plans and programs, better methods to assess and support mental health, and constant work toward equitable provision of the program. Further opportunities for study include economic analysis, qualitative assessment of the program's effects on families, detailed nutritional and growth follow-up of participants, and impact on breastfeeding.

Overall, G@H has been enthusiastically accepted by healthcare providers and families, and it has become a mainstay of management in the DCH NICU. Implementation of such a program does require investment, but the ability to bill for this service increases sustainability. Further adoption of RPM programs for babies who remain hospitalized with IOF alone will add to the increasing evidence that this method of care may be most appropriate for a subset of babies who require NICU admission.

CONCLUSION

We report here the successful implementation of an RPM program to facilitate early NICU discharge in babies with IOF as their only barrier to hospital discharge. While we found the moderately preterm population to be the most common utilizers, babies of all gestational ages and with varying levels of medical complexity were able to participate. We look forward to further improving the program, supporting other NICUs who would like to create an RPM program, and investigating economic, psychosocial, and nutritional impacts of the program.

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AUTHOR CONTRIBUTIONS

CF carried out the initial analysis and interpretation of the data, drafted the initial manuscript, and reviewed and revised the manuscript. MH carried out final analysis of the data, reviewed and revised the manuscript. AD and AK conceptualized and designed the study, participated in acquisition of data, and reviewed and revised the manuscript. JBW conceptualized and designed the study, participated in and supervised data collection, participated in data analysis and interpretation, and critically reviewed the manuscript for important intellectual content. All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

COMPETING INTERESTS

The authors declare no competing interests.

ETHICS APPROVAL

The study was approved by the Institutional Review Board at Oregon Health & Science University (#19657). The study was performed in accordance with the Declaration of Helsinki.

ADDITIONAL INFORMATION

Correspondence and requests for materials should be addressed to Jamie B. Warren.