The effects of telepresence with real-time video and audio communication on parent-infant interaction and staff experience in neonatal intensive care unit

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ABSTRACT

Objective: We implemented an online visitation system named "telepresence" in the neonatal intensive care unit (NICU) for family members at home to communicate with their babies in real-time using video and audio. This study evaluated the impact of this system on families and medical staff.

Methods: Nineteen families of babies admitted to the NICU between 2022 and 2023 and 65 medical staff participated. Each family experienced two weeks of virtual visits. Changes in parental depression and attachment were assessed.

Result: Before and after telepresence, the median Edinburgh Postnatal Depression Scale score reduced from 6 to 4 ($p = 0.026$), and the Mother-to-Infant Bonding Scale score showed a decreasing trend, with both medians at 2 ($p = 0.057$). Eighty-nine percent of the parents and 97% of staff reported that telepresence did not increase parental stress, and 88% of parents felt positive changes in their baby's siblings. All parents wanted to visit their babies in person after seeing them on camera.

Conclusion: Telepresence improved parental mental health, reduced family distress, and supported connection with their infants, making them eager to visit in person.

Innovations: This technology potentially make parents want to visit more by helping them feel more connected to their infants.

1. Introduction

1.1. Background

The survival rate of very low birth weight infants in Japan has improved to 95% owing to advances in neonatal care [1]. In contrast, one in three babies has health problems, such as developmental delay or disabilities [2,3], which may be influenced by the special environmental factors of the neonatal intensive care unit (NICU) [4]. Parents of babies admitted to the NICU experience increased psychological distress [5] and are at risk of developing post-traumatic stress disorder [6]. Furthermore, the COVID-19 pandemic led to the worldwide spread of restrictions on NICU visits [7], and it has been pointed out that the increased physical and psychological distance between parents and babies may lead to long-term deterioration of the parent's mental health

[8].

Daily visits by parents to the NICU are associated with a lower incidence of behavioral abnormalities in preterm infants [9] and the practice of family-integrated care, in which parents take the initiative in childcare during NICU admission, is beneficial for reducing maternal stress and in the formation of parent-child relationships [10-12]. Therefore, in our NICU, we supported families to take the initiative in their care, practiced 24-h and sibling visitations, and renovated the facility in 2019 to include private rooms with family beds, expanded bedside spaces, and provided a cozy light-sound environment.

However, families cannot always stay in the NICU, not only because of the COVID-19 pandemic but also for various social reasons, such as the remoteness of their homes and the presence of older siblings. In 2000, Gray introduced an alternative method of sharing NICU videos online with families [13]. Since the onset of the pandemic, many global

Table 1
Participant characteristics.

Staff		$n = 65$
Occupation	Neonatologist	14 (22)
	Nurse	51 (78)
NICU experience (years)	<1	8 (12)
	2–5	22 (34)
	5–10	15 (23)
	10–15	9 (14)
	>15	9 (14)
	No answer	2 (3)
Age	20s	23 (35)
	30s	27 (42)
	40s	11 (17)
	50s	2 (3)
	No answer	2 (3)

Parents		$n = 35$
Gender	Male	16 (46)
	Female	19 (54)
Age (years)		35 (31–38)
Family income (million yen)	3.5–5.5	4 (21)
(19 families in total, total value)	5.5–8.5	10 (53)
	>8.5	5 (26)
Final education	High school	4 (11)
	Junior college/Vocational school	9 (26)
	University	21 (60)
	No answer	1 (3)
In-person visit frequency (days/week)		6 (2–7)
In-person visit time (minutes/visit)		180 (105–240)
Online visit frequency (days/week)		7 (4–7)
Online visits time (minutes/visit)		30 (15–30)

Values are expressed as either median (interquartile range) or n (%).

clearly understood. Previous studies have primarily focused on video communication to allow parents to observe their infants' condition. However, our study has incorporated both video and audio communication to facilitate real-time interaction between parents and their infants, providing a more comprehensive connection.

Telepresence refers to technology that provides the feeling of being together even at a distance. Unlike one-way communication, in which parents can only see their babies, two-way communication allows for interactive exchanges during which parents can not only see but also talk to their babies and hear the sounds their babies make. This interaction is crucial for enhancing the emotional connection between parents and their infants. Two-way communication supports more natural interactions, similar to in-person visits, thus potentially reducing parental stress and promoting better mental health outcomes. We named our online visitation system "telepresence," which enabled family members at home to interact with their babies in the NICU in real-time using video and audio. This system allows families to see and talk to their babies at any time, and two-way audio communication is possible when NICU staff is present. Our goal with telepresence is to bridge the gap between hospitals and homes as much as possible by enhancing family engagement and reducing stress. This study aims to evaluate the overall impact of telepresence on families and NICU staff.
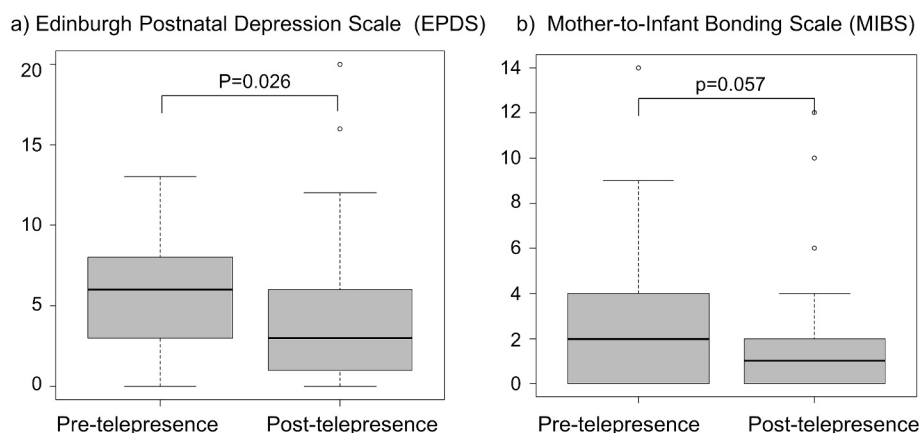
2. Methods

2.1. Design

This prospective observational study was conducted in a tertiary NICU with 48 beds and approximately 400 admissions per year in Kanagawa Prefecture, Japan. The NICU includes both open wards and private rooms, and the study was carried out in both environments depending on the location of the infants during the study period.

2.2. Sample

Caregivers of babies admitted to the NICU between September 2022 and February 2023 who had been or would be hospitalized for at least one month and medical staff who worked in the NICU during the study period were eligible to participate in the study. Participants were recruited through a hospital announcement and all interested parents were invited. This voluntary approach ensured open and inclusive participation.

facilities have explored options such as asynchronous video messaging [14] and technologies that enable families to remotely watch their babies in real-time.

Several studies have shown that webcams are often used by families facing challenges with in-person visits [15], and that they have been shown to increase breast milk production in mothers [16]. Although parents of infants in the NICU are generally willing to use webcams [17-20], the specific impacts on their mental health, bonding with their infants, and the workload and stress levels of the staff have not been

Fig. 1. Changes in parental depression and infant bonding before and after telepresence.
The boxes show the median (50th percentile) and interquartile (25th and 75th percentiles) ranges, and the whiskers represent the 5th and 95th percentiles. Dots represent outlier values. Both scales have a maximum score of 30 points, with higher EPDS scores indicating worse depression and higher MIBS scores indicating more problematic bonding. Pre- and post- telepresence, the median EPDS score was 6 (interquartile range [IQR] 3–7) vs. 4 (IQR 1–6), and the median MIBS score was 2 (IQR 0–4) vs. 2 (IQR 0–2), respectively.

Table 2

Questionnaire for parents (Likert scale responses).

Question	Group	n = 35
Q1. I felt good when I saw my baby on the camera.	Agree	29 (83)
	Slightly agree	5 (14)
	Slightly disagree	1 (3)
	Disagree	0 (0)
Q2. I felt helpless when I saw the baby on the camera.	Disagree	16 (46)
	Slightly disagree	12 (34)
	Slightly agree	6 (17)
	Agree	1 (3)
Q3. I felt anxious when I saw the baby on the camera.	Disagree	18 (51)
	Slightly disagree	9 (26)
	Slightly agree	7 (20)
	Agree	1 (3)
Q4. My milk secretion increased. (Only mothers answered, *n* = 19)	Agree	2 (11)
	Slightly agree	2 (11)
	Slightly disagree	11 (57)
	Disagree	4 (21)
Q5. I was happy to be able to show my baby to my siblings. (Parents with siblings, n = 18)	Agree	18 (100)
	Slightly agree	0 (0)
	Slightly disagree	0 (0)
	Disagree	0 (0)
Q6. I felt a positive change in my siblings before and after the online visit. (Parents with siblings, *n* = 18)	Good change	8 (44)
	Slightly good change	8 (44)
	No change	2 (11)
	Slightly worse change	0 (0)
	Bad change	0 (0)
Q7. I was happy to be able to show my baby to grandparents and friends. (Parents who showed their babies to grandparents or friends, *n* = 21)	Agree	18 (86)
	Slightly agree	3 (14)
	Slightly disagree	0 (0)
	Disagree	0 (0)
Q8. I felt that it had a positive effect on my baby's development.	Agree	11 (31)
	Slightly agree	16 (46)
	Slightly disagree	7 (20)
	Disagree	1 (3)
Q9. I felt that the presence of babies was a part of my life at home.	Agree	20 (57)
	Slightly agree	10 (2)
	Slightly disagree	4 (11)
	Disagree	1 (3)
Q10. When I saw the baby on the camera, I wanted to touch and see the baby more.	Agree	26 (74)
	Slightly agree	9 (26)
	Slightly disagree	0 (0)

Table 2 (*continued*)

Question	Group	n = 35
	Disagree	0 (0)
Q11. Since I can see the baby on camera, I don't need to see the baby as often.	Disagree	19 (54)
	Slightly disagree	14 (40)
	Slightly agree	1 (3)
	Agree	1 (3)
Q12. Online visitation has increased my overall stress.	Disagree	22 (63)
	Slightly disagree	9 (26)
	Slightly agree	4 (11)
	Agree	0 (0)
Q13. I would like to use online visitation in the future.	Agree	29 (83)
	Slightly agree	4 (11)
	Slightly disagree	0 (0)
	Disagree	2 (6)

Values are expressed as n (%).

2.3. Methods

We used the Osaka-N system developed by Osaka University Hospital in collaboration with Dowell and Atom Medical Corporation. This system was used for six months as a means for families to see their babies at any time. Through a small camera installed by the baby's bedside, family members could access the system directly from their mobile devices and see the baby in real-time. Family members could simultaneously connect from multiple locations. A tablet installed by the baby's bedside showed the family members' images, and an external speaker output the family members' voices. In addition, a small camera output the baby's image to the family's mobile device and an external microphone output the sound around the baby. To ensure privacy, the camera was positioned and adjusted specifically to focus on the bed of the target baby, ensuring that other babies did not appear in the image. The position of the tablet screen was adjusted so that the baby could see the family members in their field of vision. Although the images and audio were bidirectional, when the staff left the NICU, the audio on the NICU side was turned off so that the family could not hear the sounds, unless necessary.

In the NICU, three systems were available that allow simultaneous use by up to three families. Each family was allocated a two-week visitation period. The system allowed parents to see and talk to their babies between 8:00 a.m. and 9:00 p.m. This restriction was implemented due to the challenges of staff availability and response capability during overnight hours, ensuring reliable access and support during the designated times. The terminal and the baby were linked using a barcode reader, and families registered their e-mail addresses. When the family accessed the camera, a passcode was sent to the e-mail address, and the connection was established through a two-step verification. To ensure privacy, the system did not have a recording function and no streaming data were stored in the cloud. Due to the COVID-19 pandemic, direct visits to the NICU were restricted to parents only and limited to 10 hours daily, from 12:00 p.m. to 10:00 p.m., during the study period.

2.4. Evaluation methods

The evaluation methods used in this study were as follows: first, the Edinburgh Postnatal Depression Scale (EPDS) and the Mother-to-Infant Bonding Scale (MIBS) were used to assess caregiver depression and attachment formation before and after the introduction of telepresence. The EPDS, a questionnaire developed by Cox to screen for postpartum

Table 3

Questionnaire for parents (open-ended questions).

a) When to use telepresence
During commute, or lunch break at work
When waking up
When eating with siblings or grandparents
Keeping it on during daily life

b) Changes in siblings
Initially, our other children were quite jealous when we went to visit the baby, but after experiencing telepresence, they happily encouraged us to go, even suggesting things we could do for the baby like expressing milk.
The baby's name naturally became part of our everyday conversations
They enjoyed reading and singing to the baby via telepresence, activities they'd do if the baby were physically with them

c) General Comments
It was wonderful to be able to show our baby to my grandparents who live far away.
Even when sick, I could quickly connect with the babies, making me feel close to them and calm
It was hard for me to feel attached to my child when I was far away and busy, but knowing about his day makes me feel close and want to visit soon.
It was good to know how my husband, who is working, feels about the child because he is connected frequently.
I was happy to see the reactions of the babies when I called out to them and wondered if they could hear me.
I could feel the daily growth of my child.

d) Issues and requests
It was sad to see that the staff did not come immediately even when the child kept crying.
Accidentally hearing the staff's conversation left me feeling distressed.
I would like to be connected 24 h a day.
I would like to hear the hospital's voice at all times

depression, is used in many countries [21]. The MIBS is a revised version of the Mother-Infant Bonding Questionnaire (MIBQ) [22] developed by Kumar to assess postpartum bond formation disorders; we used its Japanese version (MIBS-J) [23,24]. Both questionnaires consisted of ten items which were answered on a four-point Likert scale. Next, to evaluate telepresence in general, caregivers and staff were asked to respond to a questionnaire developed by the authors. The caregiver questionnaire included a Likert scale and open-ended questions to assess their demographic factors such as socioeconomic status, family structure, and geographic location, alongside visitation status and telepresence evaluation. Similarly, the staff questionnaire was anonymous and comprised a Likert scale and open-ended questions about these demographic factors and the impact of telepresence on the families under study and on the staff's work.

2.5. Data collection

Caregivers were provided with a pamphlet containing a QR code before and after their participation in the study, and were asked to respond to the questionnaire. For staff members, an announcement with a QR code was displayed and they were requested to provide their responses.

2.6. Statistical analysis

Using the Wilcoxon signed-rank test, the data were presented as medians and interquartile range (IQR)s. All statistical analyses were performed using EZR (Saitama Medical Center, Jichi Medical University, Saitama, Japan), which is a graphical user interface for R (R Foundation for Statistical Computing, Vienna, Austria). More precisely, it is a modified version of the R commander designed to add statistical functions frequently used in biostatistics.

2.7. Ethics

The study protocol was conducted in accordance with the principles contained in the Declaration of Helsinki and was approved by the local

institutional review board (No. 138–11) and written informed consent was obtained from the parents of all infants and the medical staff.

3. Results

3.1. Participant background characteristics

Nineteen families (19 fathers and 19 mothers) participated in the study, all of whom were the parents of their babies. Thirty-five participants (16 fathers and 19 mothers) responded to the survey questionnaire. Sixty-five medical staff members (14 neonatologists and 51 nurses) participated in the study. Table 1 presents the participant background. The median birth week was 27 weeks (IQR: 27–31), the median age at the start of telepresence was 41 days (IQR: 28–58), and 12 (63%) babies had siblings. Thirty parents (12 fathers and 18 mothers) completed the EPDS/MIBS both before and after telepresence; the EPDS scores showed a significant decrease after telepresence, whereas the MIBS scores tended to decrease (see Fig. 1).

3.2. Family questionnaire

3.2.1. Impact on parents

When scores for "agree" and "somewhat agree" were combined, 97% of parents felt positive seeing their babies on camera, and 89% did not feel increased stress overall; 100% of the parents reported that seeing their babies on camera increased their desire to visit in person, and 94% expressed a wish to continue using online visitation. However, a few parents mentioned feeling uncomfortable listening to staff conversations through NICU audio (Tables 2 and 3).

3.2.2. Impact on siblings

Of parents who had other children, 88% indicated that they saw positive changes in those children. Feedback from the open-ended questions was generally positive. Feedback from parents highlighted the changes in sibling behavior. Siblings who were previously jealous of their parents' presence at the hospital became more supportive of activities such as expressing breast milk and visitation. In addition, they

Table 4
Questionnaire for staff (Likert scale responses).

Question	Group	n = 65
Q1. I feel that online visitation increases family stress	Disagree	24 (37)
	Slightly disagree	39 (60)
	Slightly agree	2 (3)
	Agree	0 (0)
Q2. I feel that online visitation makes family members more anxious.	Disagree	25 (39)
	Slightly disagree	36 (55)
	Slightly agree	4 (6)
	Agree	0 (0)
Q3. I feel that online visitation makes family members feel more helpless.	Disagree	24 (37)
	Slightly disagree	34 (52)
	Slightly agree	6 (9)
	Agree	0 (0)
	No answer	1 (2)
Q4. I feel that online visitation has a positive effect on the baby's development.	Agree	27 (42)
	Slightly agree	34 (52)
	Slightly disagree	4 (6)
	Disagree	0 (0)
Q5. I feel that it has a positive effect on babies.	Agree	52 (80)
	Slightly agree	13 (20)
	Slightly disagree	0 (0)
	Disagree	0 (0)
Q6. Frequency of family visits has increased due to online visitation.	Increased	7 (11)
	Slightly increased	13 (20)
	No change	42 (65)
	Slightly decreased	1 (2)
	Decreased	0 (0)
	No answer	2 (3)
Q7. Online visitation causes more stress for the medical staff.	Disagree	8 (12)
	Slightly disagree	39 (60)
	Slightly agree	17 (26)
	Agree	0 (0)
	No answer	1 (2)
Q8. Online visitation is a work burden for the medical staff.	Disagree	2 (3)
	Slightly disagree	36 (55)
	Slightly agree	26 (40)
	Agree	0 (0)
	No answer	1 (2)
Q9. The online visiting system can be used as a means of communication between patients and their families.	Agree	30 (46)
	Slightly agree	30 (46)
	Slightly disagree	5 (8)
	Disagree	0 (0)
Q10. It would be good if the NICU had an online visiting system.	Agree	52 (80)
	Slightly agree	13 (20)
	Slightly disagree	0 (0)
	Disagree	0 (0)

Table 4 (*continued*)

Values are expressed as n (%).

began to naturally mention the baby in daily conversation, read books to the baby, and sing songs to the baby (Tables 2 and 3).

3.3. Staff questionnaire

When scores for "agree" and "somewhat agree" were combined, 41% and 27% of the staff felt that the workload and stress, respectively, would increase. However, 97% of the staff answered that this system did not increase family stress. Furthermore, 94% and 100% of the staff felt the system could positively impact the child's development and siblings, respectively. All staff members felt that having this technology in the NICU was beneficial. Responses to the open-ended questions were generally positive; however, there were some comments regarding the workload and requests for the system (Tables 4 and 5).

4. Discussion and conclusion

4.1. Discussion

In this study, the introduction of telepresence reduced parental depressive symptoms and enhanced their attachment to children, contributing to improved mental health. It also reduced parental stress and led to positive changes in siblings. Furthermore, we observed that telepresence could increase parents' motivation for face-to-face visits and engagement with their babies. These findings suggest that technology-mediated interactions between parents and babies positively impact parental mental health.

There have been various reports on the effects of webcams on parental stress [20,25]. Previous studies have indicated that most staff believe webcam use increases parental stress, due to concerns that continuous monitoring might lead parents to misinterpret medical situations and increase inquiries and demands on staff. Despite these concerns, data have shown a significant decrease in actual parental stress, revealing a discrepancy between staff perceptions and family needs [18]. In contrast, approximately 90% of the parents and staff in our study agreed that telepresence reduced parental stress, possibly because the staff witnessed positive changes in families and siblings. Despite concerns about increased staff stress from webcam introduction [17] and some reports confirming this [18], many staff members in our study did not experience an increase in stress. This may be attributed to observing the child's integration into family life, being cared for as a family member, and improved communication between the family and staff, leading to better care.

In a previous study, the majority of staff and parents believed that web cameras did not decrease the time that parents spent in the NICU [4]. In this study, all parents expressed a preference for visiting the NICU whenever possible. The findings suggest that telepresence significantly enhanced their desire for more frequent in-person visits by deepening their emotional connection with their infants. In addition, interactions with siblings are considered important in family-centered perinatal care

Table 5
Questionnaire for staff (open-ended questions).

a) Impressions
I felt that it had a positive effect on the babies' growth and development when they responded to voices and opened their eyes.
I was happy and comforted to know about the family's reactions and how the siblings interacted with the baby through the web camera.
The siblings' voices created a cheerful atmosphere in the NICU.
It was good to be able to communicate with family members who couldn't visit often.
Seeing the family members on the other side of the screen, I felt that the baby was truly welcomed as a part of family
It's reassuring for parents to be able to see their children, even for short periods, like before bedtime or during commutes.
All the families who participated were satisfied with the system, so I would like to see it introduced to the NICU.
It's a way for babies in the NICU to be a part of their families.

b) Challenges
The system's registration process is too complex.
Adjusting the camera position each time is difficult.
We would like a feature that lets us know when family members connect to the system.

[25]. Our study revealed positive responses from siblings, suggesting that telepresence may strengthen the bond between siblings and positively affect the mental health of the entire family.

While many previous studies have not used audio due to security concerns that staff conversations and information about other family members could be misinterpreted, this study employed it recognizing, the importance of "bringing the family's voice to the child." Although audio has the potential to strengthen the parent-baby bond, some families experienced anxiety during interactive voice exchange, as reported in Table 3. These instances included delayed staff responses to a crying child or accidental overhearing of distressing staff conversations. Interactive voice communication is advantageous in web camera systems because it allows families to feel more connected with their babies. However, it is essential to develop technology that makes it easier for staff to be aware when a family member is accessing the system.

This study has several limitations. First, there may have been a bias toward positive perceptions of the web camera system among participants. Participants were recruited through hospital notices, likely attracting more engaged parents. These parents might have had a more positive perception of the telepresence system and a desire to see the intervention succeed. Secondly, most of the parents who participated in the study already had high frequencies and durations of in-person visits, leaving the impact on parents with less frequent visits unclear. Thirdly, the negligible difference observed in the MIBS scores might be attributed to the initial targeting of parents with frequent visitation and strong bonding, although a downward trend was still noted. Fourthly, the use of the system was restricted to two weeks for families and six months for staff, with limited access times and voice communication. This did not strictly replicate the original concept of telepresence, in which families could see their children at any time. As the study expands in scope and duration, its effects on the mental health of both staff and parents should be continually evaluated.

4.2. Innovation

In this study, we introduced a novel technology that can be "integrated" into the daily lives of families with infants in the NICU. Named "telepresence," this online visitation system facilitated real-time two-way video and audio communication between families at home and their babies in the NICU. Our telepresence system adapts to the diverse backgrounds of families, enabling flexible responses to their unique situations. By providing continuous and meaningful connections, it strengthens family bonds, particularly when physical visits are limited. This system supports families by enhancing their sense of closeness and involvement, which is crucial when they cannot be physically present.

4.3. Conclusion

Telepresence was beneficial to both families and staff, with a particularly notable positive impact on parents by reducing their distress. It also positively affected siblings. Interestingly, online interactions between parents and their children increased the parents' willingness to visit their children in person. Although potential challenges such as increased workload for staff and the need for careful communication should be noted, telepresence has proven to be a valuable technology that complements and enhances family-integrated care.

CRediT authorship contribution statement

Tomoko Saito: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Data curation, Conceptualization. **Tomoyuki Shimokaze:** Writing – review & editing, Supervision, Conceptualization. **Miku Niizuma:** Investigation, Data curation. **Masako Suzuki:** Investigation, Data curation. **Makiko Toyoshima:** Investigation, Data curation. **Katsuaki Toyoshima:** Supervision, Methodology, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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