Published in final edited form as:

Am J Primatol. 2009 June ; 71(6): 510–522. doi:10.1002/ajp.20681.

Successful Behavioral Strategy to Unite Mother and Infant Rhesus Monkeys (*Macaca mulatta*) After Cesarean Delivery

ANGELA M. RUGGIERO^{1,*}, MATTHEW F.S.X. NOVAK¹, RUTH A. WOODWARD², and STEPHEN J. SUOMI¹

¹Laboratory of Comparative Ethology, Department of Health and Human Services, Eunice Kennedy Shriver National Institute of Child Health and Human Development, National Institutes of Health, Poolesville, Maryland ²Department of Health and Human Services, Research Animal Management Branch, Eunice Kennedy Shriver National Institute of Child Health and Human Development, National Institutes of Health, Poolesville, Maryland

Abstract

Developmental studies of pre- to postnatal continuities in rhesus monkeys sometimes require infants be reared with their mothers. However, complications during pregnancy or experimental designs may require cesarean delivery. Owing to lack of published information on this subject, strategies are needed to introduce mothers to their infants following cesarean delivery. Using positive and negative reinforcement techniques we attempted to unite six infant rhesus macaques, *Macaca mulatta*, to their mothers following c-sections. For our seventh subject, we attempted to cross-foster an infant onto an unrelated female after she had undergone a cesarean surgery for a late-term spontaneous abortion. The mothers varied in age, parity, previous postnatal mothering experience with infants, housing earlier to delivery, and housing subsequent to introduction. Although there were large individual differences among the mother–infant pairs, all seven introductions were successful. The mothers learned to accept and care for their infants from the continuous application of operant conditioning techniques. These data suggest that mother-rearing following cesarean section is a realistic possibility whether required for clinical reasons or for proper experimental control. Furthermore, the ability to successfully mother-rear infants produced from cesarean delivery lessens the impact this potential confound of not being reared by their mothers exerts on many types of developmental studies

Keywords

mother-infant introduction; cesarean delivery; mother-rearing; *Macaca mulatta*

*Correspondence to: Angela M. Ruggiero, Laboratory of Comparative Ethology, Eunice Kennedy Shriver, National Institute of Child Health and Human Development, NIH Animal Center, P.O. Box 529, Poolesville, MD 20837. ruggiera@mail.nih.gov.

†This article is a US government work and, as such, is in the public domain in the United States of America.

INTRODUCTION

Developmental studies that assess gene by environment interactions often compare various types of pre- and postnatal rearing to assess variations in developmental outcome. In these studies the ability to mother-rear, or to randomly assign births to differential rearing conditions, is essential. Unfortunately, cesarean section delivery of infants imposes significant limitations on experimental designs because of the belief that macaque mothers will reject infants born via cesarean section.

Cesarean sections may be a necessary part of clinical care in laboratories that breed macaque (*Macaca* sp.) monkeys. Historically, colonies have had difficulty introducing macaque infants to their mothers following cesarean delivery. In our own facility, numerous undocumented attempts had been made over the years without the use of any operant conditioning techniques and only 1 remembered attempt had been successful. There are not many published data on success rates for introductions [Lundblad & Hodgen, 1980; Meier, 1965, 1982]. Despite the commonality of cesarean sections, documentation of attempts to reunite infants with mom are not prevalent in the literature or are often lacking detail. Only recently have laboratories begun to achieve and report success [Bellanca et al., 2006; Falkenstein et al., 1998].

Falkenstein et al. [1998] used a passive approach for uniting the mother and infant. The infant was rubbed with fluid-soaked laparotomy pads from surgery and placed in the cage with their mother. Then mother–infant interactions were observed. The first introduction was attempted in the afternoon on the day of surgery as soon as the mother recovered from general anesthesia. If the mother did not accept the infant, repeated attempts were made across 4 days. The attempts usually lasted an hour, but if the mother displayed affiliative behaviors toward the infant they were left together longer. Of the 14 mother–infant introductions attempted, 10 were successful. In pigtailed macaques, *M. nemestrina*, Bellanca et al. [2006] used a more direct approach to unite mother and infant to achieve a 100% success rate in four out of four mother–infant introduction attempts. The infant was rubbed with the placenta and the mother’s vaginal secretions, then placed right on the mother’s ventrum near her nipples. Behavioral observations were collected to monitor the mother and infant. Similar to Falkenstein et al. [1998], if the mother did not initially accept the infant, repeated attempts were made the following day, about 48 hr postsurgery. None of the introductions required more than three attempts over the course of 3 days and three out of four were successful within an average of 2 hr from first contact.

At our facility, an ongoing research project on maternal–fetal to maternal–infant continuities requires mother-rearing. After successfully introducing two mothers and their infants for that project, we further applied our procedures to assess whether the technique would be successful in our larger breeding colony. Anecdotally, there were no historical cases at our facility of a mother accepting a cesarean born infant after the first postnatal day. In fact, there was only one remembered successful introduction in the 20-year history of the breeding colony at the Laboratory of Comparative Ethology (LCE; personal communications: S. Higley, colony records manager, and C. Shannon-Lindell, former nursery manager). Our former methods of introduction involved placing the infant in the

recovery cage with its mother and observing the pair for a period of approximately 2 hr over the course of several days to see if the mother exhibited maternal behaviors toward the infant. The first attempts were made after the mother had fully recovered from surgery and then repeated attempts were made again on subsequent days. If the mother had not accepted her infant by the fourth day postsurgery, no further attempts were made. We also tried placing the infant on mom, yet not as persistently as the procedure outlined in this report. If the mother continued to fight off our attempts, we stopped after at least ten tries. Owing to the failure of our previous attempts, most infants born via surgical delivery were reared in our nursery facility. If our new technique proved successful, introduction of infants to mothers following c-sections could increase species typical rearing conditions in our colony and allow more experimental flexibility in assignment of infant macaques to postnatal developmental studies, including studies involving the effects of gene–environment interactions.

METHODS

Subjects

Seven mother–infant pairs of rhesus macaques (*M. mulatta*) were used for this study. Six mother–infant pairs consisted of the pregnant mother and her resultant infant. The seventh mother–infant pair consisted of a pregnant female who had spontaneously aborted late in gestation, and an unrelated newborn. All pregnant females and the six biological infants were from the Eunice Kennedy Shriver National Institute of Child Health and Human Development's Laboratory of Comparative Ethology (LCE). The infant for the seventh mother–infant pair came from Virginia Commonwealth University (VCU). Before receiving the infant from VCU, one of our breeding colony females (Female 7) had just undergone a cesarean surgery for a late-term spontaneous abortion earlier that day. Female 7's infant had died in utero but was near term; the colony veterinarian assessed that the female was likely to be capable of lactating and supporting a fostered infant. As a result we attempted to cross-foster the newly born infant from VCU onto Female 7.

Before cesarean surgery four of the pregnant females were socially housed in our breeding groups, two were socially housed in our breeding groups but cage housed during pregnancy and one was socially housed in our field station breeding group.

Assignment of animals to this project was not random. Over a 39-month period from April 2005 to July 2008, our colony veterinarian determined that 23 females required cesarean sections. Of those 23 females, we were able to try mother–infant introductions on seven of them. The rationale for not conducting introduction attempts on the other 16 cesarean sections included (1) in four cases, the infant had died in utero, (2) in nine cases, the resultant infants were assigned to our nursery rearing paradigm to fulfill ongoing experimental needs, and (3) for the remaining three cases, the infants required significant post delivery clinical intervention (e.g. premature, low birthweight, failure to thrive) and nursery rearing. Therefore, we intervened with all available pregnancies during the time period of this study. This resulted in mothers of various ages, parity, rearing history and reason for surgical delivery (see Table I). All infant subjects were assessed at delivery as healthy, bright, alert and responsive.

Procedures

All procedures in this article comply with research protocols that have been reviewed and approved by the NICHD Animal Care and Use Committee. The Laboratory of Comparative Ethology of The Eunice Kennedy Shriver National Institute of Child Health and Human Development at the National Institutes of Health is an AAALAC International accredited facility; as such its policies are in accordance with those from the USDA Animal Welfare Act, the Public Health Service Policy on Humane Care and Use of Laboratory Animals and the *Guide for the Care and Use of Laboratory Animals*.

Cesarean Section

The decision to perform a c-section is multi-faceted and includes signs of fetal distress, signs of maternal distress, maternal delivery history, progression to delivery and clinical judgment. Pregnant females received abdominal ultrasounds on days 10 and 14 after previously determined delivery due date to evaluate progression toward delivery.

Fetal distress indicators were abnormal fetal heart rates (<120 bpm,>200 bpm), fetal colon width (>9 mm), presence of meconium in colon, agonal gasping in utero, aging of placental disc, decreased/absent amniotic fluid and flocculent material in the amniotic fluid. Fetal presentation (cephalic, breech, transverse) was also considered but it is known that the fetus can alter presentation from breech to cephalic immediately before delivery so it is not used as a reliable indicator of dystocia.

Maternal distress indicators were active labor>7 hr, lying prone for extended periods, lethargy and obturator nerve impingement/paralysis. The length and appearance of cervix (softening and/or dilation of inner and external cervical os) were also evaluated via prepartum exams to monitor progression to delivery. Maternal history was also taken into consideration, but animals in our colony that have had c-sections owing to fetal distress have been able to successfully delivery healthy infants vaginally in subsequent pregnancies.

The females were sedated with ketamine hydro-chloride (Ketaset, 10 mg/kg IM, Fort Dodge Animal Health, Overland Park, KS) for ultrasound evaluation on days 10 or 14 post-predetermined delivery date. Those females that required cesarean delivery were then sent to the surgical suite where a peripheral catheter was placed. They were intubated and a surgical plane of anesthesia was maintained using Isoflurane. Cephalexin (Ancef, 25 mg/kg IV, Glaxo Smith Kline, Research Triangle Park, NC), ketoprofen (Ketofen, 2 mg/kg IM, Fort Dodge Animal Health, Overland Park, KS) and an initial dose of 0.25 ml buprenorphine (Buprenex, 0.3 mg/ml IM, Reckitt Benckiser Healthcare (UK) Ltd.,) were administered. A surgical clip and preparation was performed. A midline incision was made to exteriorize the uterus and the abdomen was packed with laparotomy sponges. Next, an incision was made into the body of the uterus and the infant was removed; the mouth was suctioned and dried then the umbilical cord was cross-clamped and cut. The infant was then given to a technician for additional postnatal suctioning and assessment. The placenta was removed and placed in a bag for use during infant introduction. The animal received 0.25 ml buprenorphine IM postinfant removal and upon completed uterine closure received oxytocin (20 IU IM). Routine abdominal closure was performed. Upon extubation and fully sitting up the animal

received the final partial dose of buprenorphine (0.5 ml IM). Postsurgical treatment included cephalexin (25 mg/kg IM/PO $\times$ BID $\times$ 7 days), Buprenex (0.03 mg/kg IM BID $\times$ 2 days or longer if necessary) and regular monitoring for signs of proper hydration, appetite and activity.

Time Frame

Mothers were allowed to fully recover from anesthesia for 3–4 hr before being exposed to the infant. In the interim, infants were taken to our nursery facility where they were placed in incubators (Thermocare ICS unit, medium model with dome cover, Incline Village, NV). The infants were fed and their body temperatures monitored. Mothers that were cage housed during pregnancy were placed back in their homecage. Mothers that had been socially housed in runs were placed in a recovery cage in a room by themselves. Typically mothers are kept out of their social group for a week to allow for proper postsurgical treatment. Approximately half the placenta, umbilical cord, and laparotomy sponges soaked with blood and amniotic fluid from the surgical delivery were left distributed in the cage with the recovering mother. This was done to emulate some of the stimuli associated with vaginal birth [Bellanca et al., 2006; Falkenstein et al., 1998]. The other half of the placenta was kept with the infant.

Previous experience in our laboratory was the main determinant of when to start and when to terminate the introductions. In our laboratory, the only successful introduction occurred when the attempts began on the day of surgery; no mother who had undergone c-section had ever accepted and reared an infant after 1-day postcesarean surgery. Therefore, despite some literature [Bellanca et al., 2006] suggesting that introduction start the following morning; we elected to make the first reunion attempts on the day of delivery. Regarding the decision of when to stop an introduction attempt, given that no mother from our laboratory accepted an infant after 3 days postsurgery and the literature suggesting that all successful introductions took no more than 4 days postsurgery [Bellanca et al., 2006; Falkenstein et al., 1998; Lundblad et al., 1980]; we used 4 days postsurgery as a limit for the length of an introduction attempt.

Once the process of successive approximations was begun for a mother–infant pair, we did not stop. The rationale was that if we were to stop at the end of the workday or for a weekend day (i.e. put the infant back in the nursery for the evening and intending to start again later) without the mother accepting the infant, then we would be inadvertently reinforcing the mother for rejecting the infant. Therefore, once initiated, introduction proceeded continuously 24 hr per day.

If, after 4 days postsurgery the mother continued to show no interest in the infant (i.e. no infant directed behavior; affiliative, exploratory or otherwise), had no contact with infant and ignored the infant, the introduction would be terminated. In addition, as we are constantly monitoring the health status of both the mother and the infant, if at any point in the introduction process the mother or infant became sick or injured and our facility veterinarian deemed them unfit for continuing the introduction, the attempt would be terminated.

Clinical Care of Infant

Health status of the infants was constantly monitored during the introduction process. Infants that were not observed to be feeding on the mother's nipple were briefly removed every 2 hr for bottle-feeding (infant formula = 1 scoop (34 g) of Primilac, Bio-Serv, Frenchtown, NJ, reconstituted in 350 ml water, added to 217 ml Similac, Abbott Laboratories, Abbott Park, IL). Rectal temperatures were also taken in conjunction with the feedings. If the infant was hypothermic (below 36.4°C) they were warmed manually using a heat lamp before being returned to mother. A typical removal lasted 30 min and because the infant was not on the mother during this time, the mother was not sedated when we removed the infant. Infants that were observed to have difficulty maintaining body temperature were given assistance in the introduction cage via heat lamps and heat pads.

Behavioral Strategies for Introductions

Positive reinforcement: Our goal was to create an environment maximizing the probability of the mother holding and nursing the infant. Therefore, we set out to reward the target behavior every time it was achieved. Ultimately, we wanted the mother to nurse the infant, holding it on the ventrum and nipple. As conditioning proceeded, we used a schedule of successive approximations to reward the mother. For example, first she was given a food reward every time an experimenter came in the room, then she would be rewarded with a food treat for being on the same half of the cage as the infant, then for being in contact with the infant, then for allowing the infant to cling to her, then for holding the infant, for allowing the infant to nurse, and for holding the infant while locomoting.

Negative reinforcement: The initial probability of the target behavior occurring naturally was judged to be very low. Therefore, after the first couple hours of positive reinforcement, a second conditioning process was also implemented. Here the experimenter served as a negative stimulus as they began to condition the mother to accept her infant. Previously, the positive reinforcement served as a way to acclimate the mother to the experimenter's presence and associate the infant with positive rewards, but now, with the experimenter taking a more active role in the introduction by reaching in the cage and physically trying to place the infant on the mother, the experimenter's manipulations (and thusly their presence) became a negative stimulus. To remove the negative stimulus of the experimenter's presence, the mother had to hold the infant. The experimenter would remain in the room until the target behavior from the successive approximation schedule was achieved. If the mother would not come in contact with the infant, the experimenter would manually place the infant in contact of the mother, either on a leg, on a side, on the ventrum, or on the nipple depending on body posture of the mom and previous successes. The mother was not sedated for this process. However, proper personal protective equipment (i.e. catch gloves, double gloving with special tear resistant gloves, etc.) was worn at all times to protect personal safety. If the mother then achieved the target behavior, the experimenter would reward her with a food treat and leave the room. From here, the experimenter would watch the mother-infant interactions through one-way glass. As soon as the mother put the infant down, the experimenter would re-enter the room. If the mother did not naturally pick up the infant, the experimenter would again place the infant on the mother, and do so repeatedly, until the

mother held the infant. In this manner, the negative stimulus of the experimenter's presence could only be removed by the mother exhibiting the target behavior (i.e. holding the infant).

Mother Infant Bonding

Target behaviors for evaluating success were (1) 1st pick up—mother was observed to pick her infant up for the first time, either off the floor (which only occurred with the first female) or when the infant was in contact with their mother and as infant slipped off, the mother pulled it back onto her. (2) 1st hold—the mother held (not necessarily tightly) her infant to her ventrum for the first time. (3) 1st cradle—the mother was first observed to be actively holding the infant to her ventrum. (4) 1st observed nursing—the infant was observed to actively suckle for the first time. (5) 1st stay on—mother held the infant to her and from that time point on, she was never observed to put it down.

Ultimately success was determined by the mothers' cradling their infants and explicit observation of the mothers allowing their infants to nurse. When these target behaviors were achieved, intervals between observation or intervention of putting the infant on their mother were slowly lengthened. Once four consecutive intervals with the target behaviors of cradling or holding the infant was displayed (usually starting with 1 min intervals) the time to intervention, or observation interval, was doubled. For example, upon achieving four consecutive 10 min successes with the target behaviors being exhibited each time, a 20 min interval was used. As long as success continued, then four 40 min intervals were used, and so on. This procedure was followed until four consecutive 8 hr intervals occurred. At this point, we considered the bonding successful and stopped formal monitoring. However, both animal care and research staff would continue informal monitoring consistent with standard laboratory practice for all animals in the facility. If at any point the mother was observed to put the infant down and not immediately retrieve the infant when we entered the room, we would start over with 10 min intervals.

RESULTS

All seven introductions attempted with these procedures were successful. The mothers that were socially housed were successfully returned to their groups with their infants. All mothers raised their infants until our colony's normal weaning period of around 1 year of age. However, there was considerable individual variation in response to the introduction procedures (see Fig. 1). Female 1 picked up her infant within 15 min of starting the introduction and from that point on she never put it down. Female 3 did not pick up her infant until over 1,720 min after the start of the introductions. Finally, Female 6 took the longest to successfully unite with her infant (2,543 min). Females 1, 2, 5 and 6 were observed to be grooming their infants at some point during introduction before success was achieved, whereas the others were not seen grooming their infants at all during the introduction. Only Female 2 actively took her infant out of our hand when we attempted to place it on her. All the others were passive, in that they did not participate in keeping the infant in contact during our attempts to manually place the infant on them. At these times, the mothers either protested and removed the infant or simply endured its physical contact passively. (Complete documentation of a typical introduction can be found in Appendix A.)

Across animals, the mean latency for “1st hold” was 457.86 min (median = 212 min, range = 0–1,062 min) and for “1st pick up” 608.71 min (median = 380 min, range = 15–1,720 min). The mean latency for “1st cradle” was 680.14 min (median = 382 min, range = 160–1,860 min), whereas for “1st stay on” the average latency was 1,201 min (median = 1,154 min, range = 15–2,543 min). Finally, the mean latency to the first observed nursing bout was 1,111.71 min (median = 1,099 min, range = 252–2,398 min).

The sequence of achieving target behaviors was not the same for each pair. Once Female 1 picked up her infant, she held it and it stayed on, then she was observed to be actively cradling the infant and then nursing was observed. For Female 2 she held her infant, picked it up and then cradled it, it stayed on and then nursing was observed. Female 3 began by holding her infant, then picked it up, then cradled it, followed by its nursing and then staying on. Female 4 held her infant, it nursed, then she picked it up, cradled it, then it stayed on. Female 5 held her infant, cradled it, picked it up, it nursed, then it stayed on. Female 6 picked up her infant, held it and cradled it all at once. Then the infant was observed to nurse followed by it staying on.

Female 7 was the most idiosyncratic owing to it being a cross-fostering attempt onto a recently c-sectioned female. The most pertinent difference was that the infant was new to our facility therefore procedures needed to be performed in quarantine. To avoid the entry and exit gowning procedures involved in quarantine, which would create long time lags between target behaviors and reinforcement, an experimenter stayed in the room with the mother and infant. For her, first she picked up the infant, then she held it, cradled it, then nursing was observed and then it stayed on.

DISCUSSION

Contrary to popular belief from early research [Meier, 1965], but consistent with recent studies, mother-rearing of infant macaques is possible after cesarean section [Bellanca et al., 2006; Falkenstein et al., 1998]. The earlier report by Falkenstein et al. [1998] may have had a lower success rate (72%) than that of Bellanca et al. [2006] (100%), but their introductions were with rhesus macaques whereas Bellanca et al. [2006] did theirs with pigtailed macaques. However, we achieved a 100% success rate with rhesus macaques. One possible explanation for our higher success rate may be persistence. Once introduction and subsequent conditioning started, there was no break. We persisted 24 hr a day until successful. However, Bellanca et al. [2006] achieved 100% success without persistence in pigtailed macaques. It is unclear whether persistence is necessary or this is a species difference between rhesus and pigtailed macaques.

Another important factor in our success rate might be the infant's ability to cling. All the infants we introduced were strong and able to hold on to their mother even if their mothers did not actively hold them. Whether these techniques would be successful in higher risk infants, i.e. those with reduced physical abilities, remains unknown.

Although these techniques worked well in our facility, successful methods may vary depending on the circumstances and species involved. It is important to keep in mind that

each mother–infant pair is unique; therefore procedures might need to be tailored to each case. In our study a good example of this is Female 7, because one of us was very familiar with this particular female we adapted our strategy to best fit the situation. Furthermore, given the myriad of potentially co-varying factors that produce success in postcesarean section mother–infant introductions, a direct test of the efficacy of different methodologies would need to be experimentally determined.

Anecdotal evidence from an eighth cesarean section suggests the effects of this technique carry over to future pregnancies. Female 2 underwent a second cesarean section after which the introduction to her infant was immediately successful without any operant conditioning. This success was achieved upon the mother recovering in the same caging, the same room and the same context as the previous conditioning sessions with her pregnancy from the previous year. Beyond this case, the strengths of these operant training procedures are further illustrated in being able to successfully cross-foster an unrelated infant onto one of our breeding colony females (Female 7) who had just undergone a cesarean surgery after her late-term fetus had died in utero.

Introductions after cesarean sections can create more flexibility for experimental designs. For instance, this may allow mother-rearing that was not previously thought possible [Lundblad & Hodgen, 1980; Meier, 1982]. Additionally, researchers are able to randomly assign infants of cesarean delivery across more kinds of rearing conditions just as infants of natural delivery are assigned, thereby minimizing the potential confounding effects of surgical delivery on postnatal developmental variables. Furthermore, control over the rearing outcome of cesarean deliveries can allow testing for interactions between delivery type and development.

As surgical delivery of infants is part of the clinical care of macaque monkey (*Macaca* sp.) breeding colonies, the ability to unite mother and infant after cesarean section is a valuable option. Further development of these techniques, including detailed documentation of introduction attempts, increases the knowledge of how to do such procedures and thus increases the likelihood that introduction procedures will be more successful. Although these procedures may not be considered routine, introducing this added level of controllability into standard operating procedures could allow researchers studying various genetic, environmental and developmental phenomena to do so more effectively.

ACKNOWLEDGMENTS

The animals used in this report were supported by funding from the National Institutes of Health Intramural Research Program. The Laboratory of Comparative Ethology of The Eunice Kennedy Shriver National Institute of Child Health and Human Development at the National Institutes of Health is an AAALAC International accredited facility; as such its policies are in accordance with those from the USDA Animal Welfare Act, the Public Health Service Policy on Humane Care and Use of Laboratory Animals and the *Guide for the Care and Use of Laboratory Animals*. We thank the animal care and veterinary staff for all their efforts. We thank the assistance of our nursery personnel. All the help we received was greatly appreciated.

Contract grant sponsor: National Institutes of Health Intramural Research Program.

APPENDIX A

11/13/06 11:00	Animal was taken to surgery. The infant was taken up to the nursery after cesarean section to warm and feed. The infant was given oxygen in the incubator as well
12:00	The lap pads from surgery that was kept with the infant in the incubator along with half of placenta was placed in the mom's recovery cage
15:00	The mom was given 0.5 ml buprenex & 1.0 ml oxytocin IM. The infant was put in the cage with the mom. The infant's temperature was 37.6°C. There was no reaction from the mom. She looked at the infant, and then moved to the front of cage to be near the heat lamp. The mom is sitting on the perch above the infant (probably closer to 15:30 when the infant was put in cage)
15:40	The mom is now lying on the floor behind the infant. When I opened the door she got up on the perch and sat by the heat lamp
16:00	The mom is still lying on the floor behind the infant. She looks really sleepy. The infant is still on the heat disk by the heat lamp
16:30	The mom is on the perch above infant. Gave the mom a couple grapes and left the room
16:32	I entered the room, the mom moved to the back of the cage. I reached in the cage to pick up the infant and put the baby on the mom. The mom refused the first couple attempts but then allowed the baby to be on her leg. Gave the mom a few treats and left
16:57	I entered the room, the baby was on the floor and the mom was sitting on the perch. The mom moved up into the back corner of the cage. I put the baby on her belly. The infant clung to her mom. I gave the mom a few treats and left the room. The mom lumbered down and tried to express milk from her nipple, then stood up. She watched the infant the whole time as it was clinging
17:15	Same as before: upon entering the room, the infant was on the floor so the infant was put on the mom again. The mom pushed at the baby, but the infant was still on the mom when I left the room
17:45	Same as before: the infant was off her mom, so I went in to put the infant on the mom. The baby was on the mom's abdomen when I left the room
18:05	I entered the room. The baby was on the floor of the cage. The infant was removed to check her temperature. The infant's temperature was 35.0°C. The infant was warmed under the heat lamp
18:15	The infant's temperature was 35.9°C. I continued to warm her under the heat lamp
18:25	The infant's temperature was 36.8°C; continued to warm her under the heat lamp. I started bottle-feeding the infant. The infant is not really suckling, very drowsy. The infant drank about 1.5 ml
18:31	The infant's temperature was 36.8°C. As the infant is now warmed and fed, I continued with the reunion. I entered the room and put the infant back on the mom, the mom pushed the infant away
18:35	The baby is still in contact with the mom, but kind of slipping off the shelf
19:00	I entered the room: the baby was on the floor of the cage under the mom who was sitting on the shelf. I put the infant back on her mom. The mom brushed the infant off with her arm, but then let the baby be put on her abdomen. Gave the mom some fruit and left the room
19:20	The baby was on the floor of the cage. I went back in the room to put the infant back on the mom. The infant was clinging on the mom's abdomen, I gave the mom treats I as held the infant to her nipple. I left the room. The baby was still on the mom 2 min later
19:40	The mom is sitting on the perch. The baby is on the floor of the cage underneath mom and vocalizing loudly. I went in to put the infant back on the mom. The mom let the baby stay on her as long as she was getting treats. I left the room. The baby stayed on mom for about 2 min, mostly on the side of her leg
20:00	The mom was given an IM injection of buprenex and ancef. The baby was taken out for a temperature check and feeding. The infant's temperature was 35.8°C. I warmed her on a heat disk while holding her under a heat lamp. I tried bottle-feeding again around 20:30. The infant drank a little, about 1–2 ml
20:40	The infant's temperature was 37.4°C. I went back in the room to put the infant back on the mom. There was the same initial reaction of the mom pushing the infant away. I left the room when the baby was on the mom's abdomen
21:00	The baby was on the floor again, vocalizing a lot. I went back in to put the infant on the mom. Again, the mom is allowing the infant to stay on her as long as she is getting treats. The infant is tolerated but not wanted
21:05	The baby is still on the mom, so I left the room
21:10	The baby is still on the mom. The mom moved across cage with the infant still on her
21:20	The baby was on the floor of the cage, so I went in to put her on her mom. Again, the mom let the baby stay on her as long as she was getting treats
21:27	I left the room. The mom started drinking from her water bottle. The baby was still on her
21:29	The baby is still on the mom. The mom was watching the baby constantly
21:30	The baby is still on the mom
21:31	The baby is still on the mom, but then fell off
21:33	I went in to put the baby back on the mom. The mom groomed the baby's belly a little
21:34	The baby came off the mom again
21:35	I went in to put the baby back on the mom. The baby was still on the mom at 21:37. I left the room

Author Manuscript

Author Manuscript

Author Manuscript

Author Manuscript

21:45 The baby slipped off the mom again. I went in to put the infant back on the mom. The mom is getting frustrated. She rejected the baby several times. She kept pushing it away. The baby was still on the mom at 21:57, so I left the room

22:30 The infant is clinging to the back of the mom's thigh. The mom is sitting on the perch in the front of the cage. I gave the mom treats and left the room

22:40 The baby fell off the mom again. I tried putting her back on her mom. Once I was able to place the infant back on, I left the room

22:50 The baby is off the mom again. I took the infant out for a temperature check. The infant's temperature was 34.8°C. I warmed the infant under the heat lamp and fed it

23:20 I went back in the room to put the infant back on her mom

23:30 The infant was off the mom again. I went back in to put it back on her. I left the room at 23:35

23:40 The infant is off the mom again. I put it back on. I left the room at 23:48

23:58 The infant is off the mom again. I put it back on. I left the room at 00:03

11/14/06 00:13 The infant is off the mom. I went in to put it back on. I left the room by 00:16

00:26 The infant is off the mom. I went in to put it back on. I left the room by 00:30

00:40 The infant is off the mom. I put it back on. I left the room by 00:48

00:58 The infant is off the mom. I put it back on. I left the room by 01:05

01:15 The infant is off the mom. I put it back on. I left the room at 01:23

01:23 The infant is off the mom. I checked the infant's temperature. It was 34.9°C. I warmed the infant up under the heat lamp and fed it. After the infant was sufficiently warmed, I put it back on the mom and was done by 01:55

02:05 The infant is off the mom. I put it back on. I left the room at 02:10

02:15 The infant is off the mom. I put it back on. I left the room at 02:20

02:25 The infant is off the mom. I put it back on. I left the room at 02:30

02:35 The infant is off the mom. I put it back on. I left the room at 02:42

02:47 The infant is off the mom. I put it back on. I left the room by 02:51

02:56 The infant is off the mom. I put it back on. I left the room by 03:04

03:04 The infant is off the mom. I put it back on. I left the room by 03:15

03:30 The infant is off the mom. I put it back on. I left the room by 03:35

03:35 The infant is off the mom again. I took the baby out to check its temperature. It was 34.5°C. Again I warmed the infant under the heat lamp and fed her. The baby and the mom are tired. The mom is losing interest in treats

04:10 I put the infant back on the mom. The mom is sitting on the perch while the baby is clinging to her thigh. I gave her a treat and left the room at 04:15

04:15 The baby is off the mom. I went in to put the baby back on the mom, but when I went to pick her up, the mom threatened me when I touched the baby. She seems protective of the infant and acting aggressive, so I left the room

05:00 The baby is clinging to the mom's outer thigh. When I opened the door to the room, the mom turned, picked the infant up, pulled it into her ventrum and cuddled it. The mom is currently grooming the infant!

05:16 The infant is in weird position, so I poked my head in the room. As I did this, the mom brought the infant up to her ventrum again. The infant is rooting and suckling. I left them alone

05:30 The mom is still holding the infant. The mom is dosing off

05:50 The baby is off the mom. I put it back on. The mom is reluctant to take the infant

05:52 The baby is still on the mom

06:00 The baby is still on the mom

06:20 The baby is still on the mom

06:40 The baby is still on the mom. The mom is moving with the baby. I gave her dried fruit treats and left

07:00 The baby is still on the mom. I left a treat and left room; now starting 40min checks

07:15 The mom was given her postsurgery meds. The baby slipped off the mom

07:20 The mom is rejecting the infant again and starting to get aggressive

07:25 The baby stays on the mom, but only briefly

07:35 Still trying to put the infant on the mom

07:39 The baby is on the mom

07:41 The baby is off the mom. I put it back on

07:44 The baby is off the mom. I put it back on

07:45 The baby is off the mom. I put it back on

07:46 The baby is off the mom. I put it back on

07:48 The baby is off the mom. I continuously put the infant back on the mom until 07:53

07:53 The baby is on the mom

08:00 The baby is off the mom on the floor of the cage. I put the infant back on

08:10 The baby is on the floor. I went in to put the infant back on. The mom allowed the infant to stay on at 08:13

08:13 The baby is on the mom

08:25 The infant is on the floor. I put it back on the mom

08:26 The infant is on the floor. I put it back on the mom

08:27 The infant is still on the mom

08:30 The infant is still on the mom

08:35 The infant is off the mom. I put it back on

08:36 The infant fell off the mom when she walked away

08:37 I went in to put the infant back on the mom

08:38 The infant is off the mom. I put it back on until 08:40

08:41 The infant is off the mom. I put it back on. The mom groomed the infant a little

08:43 The infant is off the mom. I put it back on until 08:45

08:46 The infant is off the mom. I put it back on until 08:48. The mom took a treat

08:49 The infant is off the mom. I took the infant out for a temperature check and feeding

08:50 The infant's temperature was 35.4°C. I warmed the baby under the heat lamp. I noticed an abrasion on the infant's arm with some swelling. I consulted our veterinarian. The vet palpated the area and took X-rays. There were no breaks. The infant is okay to continue with reunion. The infant was warmed up and fed about 4 ml. I returned the infant to the mom

09:40 The infant is on the mom

09:44 The infant is off the mom. I put it back on

09:45 The infant is off the mom. I put it back on until 09:47

09:47 The infant is on the mom

09:50 The infant is off the mom

10:15 The baby is on the mom. The mom is in the front of the cage, with the baby upside down on the mom's ventrum

10:25 The baby is off the mom. I put it back on

10:33 The baby is off the mom. I put it back on until 10:36

12:05 The baby is off the mom. I took the infant out for a temperature check. The infant's temperature was 35.4°C. I warmed the infant under the heat lamp

12:12 The infant's temperature was 36.3°C. I fed her 3 ml

12:30 The infant's temperature was 37.6°C

12:32 I put the infant back on the mom

12:33 The infant is off the mom

12:34 The infant is back on the mom, then the mom pulled the infant off almost immediately

12:40–12:45 I made 3–4 attempts to put the infant back on the mom

12:46 The infant is off the mom again

12:48 I was unable to get the infant back on the mom. I decided to break until things quieted down and everyone left for the day

16:00 The infant was fed, warmed and weighted. The infant's weight was 386 g

16:30 The infant's temperature was 38.3°C. I went in to put the infant back on the mom. She was still agitated. She smelled the infant, nibbled at its belly button and groomed its hand and foot, but would not let us get closer to her with the baby. I was not able to put the infant on her. I left the infant on the perch right by the mom

17:00 I gave the mom given some raisins, which she seemed to like. I left her to relax with the infant for a bit

17:30 The infant is off the mom. I went in to put it back on. The mom is still hesitant about having the infant on/near her. I got the infant on her thigh/back. I left the room at 17:40

17:50 The infant is off the mom. I put it back on her by distracting the mom with treats as I put the infant on her. I left the room at 18:00

18:10 The infant is off the mom. The infant was tired so I warmed her up and fed her. I put the baby back on the mom. Again I distracted the mom with treats and was able to put the infant right up to the mom's nipple, but the infant would not cling or suckle. I got the infant back on the mom. I left the room at 18:50

19:00 The infant is off the mom. I put it back on. I left the room at 19:10

19:20 The infant is in front of the mom, partially on her. As the mom had the infant and was holding it a little bit, I left her alone. The infant may not have been on the mom's ventrum, but close enough for now. I left the observation room at 19:25

19:35 The mom is still in the same position with the infant. The infant is in front of the mom, in her lap. It is hard to tell if/where the infant is clinging (it is not on her ventrum) but maybe lower abdomen/leg/arm. The mom has her hands holding on either side of the infant. The mom is falling asleep. I left the observation room at 19:43

19:54 The mom had moved to front of cage with her back to us. I could barely see her cradling the infant. I could not tell if the infant was suckling, but the mom had her. I left the observation room at 20:00

20:10 The infant is still on the mom. The mom is sitting on the perch with the baby in her lap. She was cradling it and holding it to her. I left the observation room at 20:15

20:30 The mom is still holding the infant. I saw the infant root around, the baby was in right area, but I could not tell if it was nursing. I left the observation room at 20:35

20:55 The infant is off the mom. The mom was given her meds, and then I put the infant back on her. I left the room at 21:10

21:20 The infant is off the mom. I put it back on her and was out of the room by 21:25

21:35 The infant is still in the same place as it had been put from before. The mom is sitting, falling asleep on the perch in the back of the cage with the baby snuggled to her leg/arm. The mom's other hand was on/by the baby. I left the room at 21:40

21:50 The infant is still in the same place with the mom. I left the observation room at 21:55

22:18 The mom is still in the same place with the baby, sleeping. I left the observation room at 22:20

22:30 The mom is on one side of the perch, the infant on the other. I went in to push the baby closer to the mom so she was in contact with her

22:40 The mom moved back to her original position. The baby is on the perch. I pushed the baby closer to the mom so they would be in contact. The baby protested. The mom got some treats. I left the room at about 22:43 with the baby in contact with the mom

22:50 The baby is on floor. The mom lunged at me when I reached in to get it. I picked up the infant and put it on the mom's leg. The baby was on the mom at 22:53

23:00 The baby is on the mom. The mom's back is facing front of cage. I left the observation room at 23:05

23:10 The baby is on the mom. The mom's back is still to the front of the cage

23:20 The baby is still on the mom. The mom has moved again and has taken the baby with her. The baby is actively rooting, but is still has not specifically been observed to be nursing

23:30 The baby is still on the mom. The baby is rooting actively

23:40 The baby's legs and waist are dangling off the perch. The mom pulls the infant onto her abdomen when I entered the room. I immediately left the room. The baby was rooting and the mom actively took the baby's head and pressed its mouth against her nipple. The baby's rooting calms down, but still could not tell if it was actively suckling. The baby is quiet, so now we move onto 20 min checks

11/15/06 00:00 The baby is still on the mom. The mom and the baby are sleeping

00:20 The baby is on the mom, both still sleeping

00:40 The mom is actively grooming the baby. The baby is leaning back on the perch. When the mom finished with grooming, she pulled the baby back into her

01:00 The baby is on the mom. Both are asleep. Now we moved onto 40 min checks

01:40 The baby is wiggling around, but still on the mom

02:20 The baby is on the mom. Both are sleeping

03:00 The baby is on the mom. Both are sleeping

03:40 The mom is sleeping. The baby is dangling from the mom who is sitting on the perch. I made a noise and woke the mom up. The mom pulled the baby up into her. The baby is rooting, but not in right spot (not near nipple)

03:45 The mom is awake. The baby is on her lower abdomen, nowhere near nipple. The mom's arms are wrapped around the baby. Go to 80 min checks, 05:00 next one

05:00 The mom is sleeping; her back is facing the front of the cage. I cannot see the infant, but I did not want to disturb the mom either. I did not see the infant anywhere else in cage or hear it cry. Therefore, I think it is still on the mom

06:00 The infant is on the mom's abdomen

07:45 The infant is off the mom, I went in the room, but did not go in the mom's cage. After a few minutes of being in the room, the mom picked up the baby. I gave the mom treats and left

08:30 The baby is on the mom and nursing!

09:00 The baby is on the mom

09:30 The baby is on the mom and nursing

10:00 I went in the observation room to check on the mom and the baby. I heard the infant screeching. It was off the mom. I left the observation room to gown up, but by the time had finished putting on all the PPE; the mom had picked up the infant. The infant is trying to cling to the mom's belly, but the mom is not holding her. The infant kept slipping a little so eventually the mom gently picked the baby up and held her

10:55 The baby is on the mom and nursing. The mom is actively holding onto the baby

12:00 The baby is still on the mom. Both are sleeping

12:30 The baby is still on the mom

13:00 The baby is still on the mom and rooting

14:00 The baby is on the mom and rooting

15:00 The baby is on the mom and nursing

16:00 The baby is on the mom and nursing. Going to 2 hr checks

18:00 The baby is still on the mom

19:45 The mom was given her meds mixed with fruit. The mom ate them immediately. The mom's water bottle was moved to the left of cage away from heat lamp. The baby is still on the mom, asleep on nipple

22:00 The baby is still on the mom. The mom is being very protective of the infant

11/16/06 00:00 Matt, the baby and the mom are all sleeping

06:00 The mom's back is to the front of the cage, but it looks like the mom and the baby are still asleep

07:30 The mom was given her medicine with biscuits and treats. The mom is acting more friendly. It does not seem like she drank much water. The baby is nursing

14:30 SUCCESS!!!!!!

REFERENCES

- Bellanca RU, Koberstein DR, Delio PJ, Kelley ST, Crockett CM. 2006 Successful introduction of *Macaca nemestrina* infants to their mothers after cesarean delivery. *J Am Assoc Lab Anim Sci* 45:27–32.
- Falkenstein KP, Bohm RP, Scamardo KA, Davison BB. 1998 Procedure for successfully introducing cesarean-delivered rhesus monkey (*Macaca mulatta*) infants to their mothers. *Contemp Top Lab Anim Sci* 37:64–68.
- Lundblad EG, Hodgen GD. 1980 Induction of maternal–infant bonding in rhesus and cynomolgus monkeys after cesarean delivery. *Lab Anim Sci* 30:913. [PubMed: 7431878]
- Meier GW. 1965 Maternal behaviour of feral-and laboratory-reared monkeys following the surgical delivery of their infants. *Nature* 206:492–493. [PubMed: 4953499]
- Meier GW. 1982 Maternal and infant behaviors following cesarean delivery in rhesus monkeys. *P R Health Sci J* 1:163–165

Fig. 1.

The time (in minutes) it took for individual mothers to achieve the target behaviors and bond with the infant. Some of the bars may not be visible or only slightly apparent owing to the small amount of time they represent. This does not mean the behaviors did not occur.

TABLE I.

The Pregnancy History of The Subject

Age (years)	Female 1	Female 2	Female 3	Female 4	Female 5	Female 6	Female 7
Place of origin	14	8	8	14	7	7	16
	Socially housed in NIH breeding group, but cage housed during pregnancy	Socially housed in NIH breeding group	Socially housed in NIH breeding group	Socially housed in NIH breeding group, but cage housed during pregnancy	Socially housed in NIH breeding group field station	Socially housed in NIH breeding group	Socially housed in NIH breeding group
Rearing history	Mother-reared	Mother-reared	Surrogate-peer reared	Mother-reared	Mother-reared	Mother-reared	Surrogate-peer reared
Parity	Multiparous (1st, 2nd and 3rd infants were mr, 4th was a c-sect and brought up to nursery to be pr; 5th infant was pr as well)	Multiparous (1st infant was pr, 2nd was mr, 3rd was spr, 4th was pr)	Multiparous (1st infant was a possible rejection but it was xf to another animal, 2nd infant was a c-sect and brought to nursery to be spr, 3rd infant was mr)	Multiparous (1st infant was stillborn, 2nd and 3rd were pr, 4th and 5th were spr)	Primiparous	Multiparous (1st infant was mr, 2nd was pr, 3rd infant was taken to nursery to be pr and for her 4th infant she was a cross foster recipient right after her own went up to nursery)	Multiparous (1st infant was pr, 2nd and 3rd were mr, 4th was spr, 5th was pr, 6th was nmr and 7th died in utero)
Known prior natural births	4	4	2	5	3 (all stillborns)	3	6
Known prior Cesarean births	1	0	1	0	0	0	0
Reason for current Cesarean section	Fetal distress/breech presentation	Lack of progression to delivery and signs of fetal distress	Lack of progression to delivery and signs of fetal distress	Fetal distress/breech presentation	Fetal distress	Maternal and fetal distress	Fetal death
Date of introduction and Cesarean section	4/7/2005	4/27/2005	2/17/2006	6/3/2006	7/14/2006	11/13/2006	6/10/2008

mr = mother-reared, pr = peer-reared, spr = surrogate-peer reared, xf = cross – fostered and nmr = nonsocial mother-reared.