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RESTORATION OF REPRODUCTIVE POTENTIAL FOLLOWING EXPIRATION OR REMOVAL OF MELENGESTROL ACETATE CONTRACEPTIVE IMPLANTS IN GOLDEN LION TAMARINS (*LEONTOPITHECUS ROSALIA*)

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Abstract: Although reversible contraception is important to successful management of small populations, there are concerns about the reversibility of melengestrol acetate (MGA), the most commonly used implant in captive animals. Female golden lion tamarins (*Leontopithecus rosalia*) placed in potential breeding situations after surgical MGA implant removal showed a 75% return to reproduction within 2 yr, unlike golden-headed tamarins (*Leontopithecus chrysomelas*), which have had a 29% return to reproduction following implant removal. This rate was indistinguishable from the breeding probability for newly formed pairs involving nonimplanted females. Litter size, stillbirth rate, and infant survival rate were not significantly different between nonimplanted and implant-removed female golden lion tamarins. However, females with implants left in (and assumed to have expired) showed higher stillbirth and infant mortality rates than did females with implants removed. For seven female golden lion tamarins for which reproductive histories before and after MGA implantation were available, litter size was unaffected by MGA implantation and subsequent removal. Infant survival rate for these females appeared to be lower after removal but was indistinguishable from rates in the nonimplanted females. Prior reproductive experience, length of time with an implant, and age of the females did not affect the probability of breeding for females after removal of the implants. Overall, breeding probability of nonimplanted females declined with age. Although the results of this study confirm the reversibility of MGA implants in golden lion tamarins, there appear to be some effects on viability of offspring, particularly offspring born to females with implants left in and presumed expired.

Key words: Melengestrol acetate, contraception, captive breeding, population management, golden lion tamarin, *Callitrichid.*

INTRODUCTION

Population growth is a vital part of zoo animal management.[10,18] Without adequate control, populations can become too large, resulting in competition for scarce resources and the placement of surplus animals at unsuitable facilities.

Growth can be controlled by various methods, including animal export, the separation of sexes during times of receptivity, maintenance of offspring within family groups after sexual maturity, maintenance of same-sex groups, sterilization, euthanasia, and contraception, which is the method of choice.[2,18] With contraception, animals are maintained in ‘‘natural’’ social situations such as family groups or in ‘‘breeding’’ pairs. Animals need not be relocated, and housing space is conserved.[3] Normal social development, which often requires normal family and social groups, is also preserved.[6]

Reversible contraception offers several advantages for genetic and demographic management of captive populations. Reproductive activity can be delayed or staggered,[3] thereby lengthening generation intervals. This approach decreases the rate at which genetic diversity is lost, increases the population's effective size by allowing more animals to contribute to the gene pool, and creates more opportunities to breed genetically important pairs.[3] Changes in population composition can also change the desirability of certain individuals for breeding. With reversible contraceptives, a female can be recalled to breeding status if her offspring fail to survive or if there is high mortality among her relatives.

Melengestrol acetate (MGA) implants are the most common contraceptives used in zoo species.[1,7,16] MGA is also an effective contraceptive in ruminants, sheep, chickens, rodents, swine, horses, domestic dogs, domestic and wild cats, deer, and goats at various dosages.[13,22] The implants contain a synthetic progesterone mixed in silastic polymer and a catalyst, and they prevent reproduction by suppressing ovulation and regular ovarian cycles.[12,21]

MGA implants have been used in captive golden lion tamarins (GLTs, *Leontopithecus rosalia*) since 1989 to help maintain the population at 500 individuals.[5] Zero population growth requires the annual breeding of only 40 pairs. Preventing reproduction among the remaining individuals is

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achieved by maintaining single-sex groups and using MGA implants. Since 1989, a total of 130 females have been implanted. The 0.2-g implants each contain 50 mg of hormone and are inserted subdermally at the nape of the neck or at the area between the shoulder blades. They probably remain effective for at least 2 yr.[3]

However, concerns about MGA implant reversibility and health effects persist. Reproductive delays and failures after removal of MGA implants have been observed in several species, including cattle and lions.[20,22] Detrimental effects on female reproductive organs have been reported in Goeldi's monkeys (*Callimico goeldii*) and squirrel monkeys (*Saimiri sciureus*),[17] common marmosets (*Callithrix jacchus*),[15] and other primates[7] and in felids.[16,20] In particular, golden-headed lion tamarins (GHLTs, *Leontopithecus chrysomelas*) may have a low rate of return to reproduction after implant removal and expiration, and smaller litters and higher infant mortality have been observed for females that have been previously implanted.[8]

Such possible detrimental implant effects have implications for continued implant use in population management programs. We studied the return to reproductive potential of GLTs following removal or expiration of MGA implants and the effect of MGA implantation on litter size and stillbirth and infant survival rates.

MATERIALS AND METHODS

Female reproductive histories were obtained from the International Golden Lion Tamarin Studbook[4] and the Association of Zoos and Aquariums Contraception Group.[7] The tamarins involved in this study were housed at multiple facilities in North America and Europe.

Implanted females

Fifty-two female GLTs that had been implanted, sometimes with multiple implants, for at least 6 mo ($\bar{x}$ = 35 mo) and had subsequently been placed in potential breeding situations for at least 5 mo following implant removal or expiration were included in the analysis. Implants are generally assumed to expire 2 yr after implantation. Implants had been removed from 21 individuals and were presumed to have expired in the other 31. Seven of the 52 GLTs reproduced both before MGA implantation and after implant removal.

Control females

Two control groups of other female GLTs were also analyzed. One group provided baseline data on probability of breeding after placement in a new breeding group. This group included 101 randomly selected nonimplanted females that had been placed into new breeding situations, either directly from their natal groups, from single-sex groups, or from previous breeding groups. A second control group to provide baseline data on litter size and stillbirth and survival rates included 287 individuals and involved all litters produced by nonimplanted females after 1989, the time period that implants were used.

Probability of reproducing

The records for each implanted and control female were examined to determine whether or not she had reproduced previously, the age when she was placed into a breeding situation, the date she reproduced, and the date and reason data collection ended. Data collection ceased because of death (of the female or her mate), removal from a breeding situation, reimplantation, reproductive senescence (14 yr), or termination of the study on 31 December 1999. Duration of implantation and whether or not the implant was removed or assumed to have expired were also recorded for implanted females.

Because the length of time that individual females could reproduce varied, a survival analysis was adapted to describe the change in rate at which females bred over time following implant removal/expiration. Parturition, rather than death, was the event studied in this analysis, and thus the calculated curves indicated the probability of breeding by time increments after implant removal/expiration, which was defined as $t = 0$. The dates when females entered the study, reproduced, or left the study were defined relative to $t = 0$. Ten females were placed in breeding situations 3–67 mo ($\bar{x}$ = 19 mo) after implant removal. They were entered into the analyses at a t value equal to the month they were placed in a breeding situation (i.e., they were left truncated). All other females were entered at $t = 0$. Females that left the study without reproducing were removed from the analysis (right censored) on the date they were no longer at risk of reproducing. Survival analysis is ideal for these data because it takes into account the amount of time females are in the study when calculating reproductive probabilities and allows for females to enter and leave the study at different times without biasing the results.[11]

Survival analyses were used to determine whether there were differences in reproductive probabilities between females with implants removed and those with expired implants, between females with prior reproductive experience and those with none, and between implanted and nonimplanted females. The probability of reproducing within a specified

Table 1. Number of female golden lion tamarins in different categories used for the analysis and mean (±SE) for age at implantation ($t = 0$) and length of time implanted.

Analysis group	No. implanted			No. controls
	Total	Implant removed	Implant expired	
Total	52	21	31	101
Proven breeder	22	12	10	8
Nonproven breeder	30	9	21	93
No. reproduced	19	13	6	62
No. not reproductive	33	8	25	39
Mean age at $t = 0$ (months)	97.3 ± 4.5	84.1 ± 6.8	106.2 ± 5.4	54.2 ± 3.1
Mean time implanted (months)	35.3 ± 3.2	22.6 ± 3.3	43.9 ± 4.3	

interval after implant removal/expiration was calculated using 1 minus the Kaplan-Meier survival estimator.[11] Cox proportional hazard models in the SAS PHREG procedure and partial log-likelihood tests were used to compare reproductive probability curves for different groups (e.g., implant removed vs. implant expired) and to simultaneously test for the effect of independent variables (age and length of time implanted).[19] Differences in reproductive probabilities were defined in terms of their proportional hazard ratios.[11]

Litter size and stillbirth and survival rates

Litter size, number of stillbirths per litter, and number of offspring surviving to day 7 per litter were recorded for each previously implanted and control female. Prior maternal reproductive experience and age of female at time of parturition were also recorded for every litter. For implanted females, we recorded the duration of implantation and collected data on only the litters produced after implant removal or assumed expiration. Spontaneous abortions were included in these rates.

A *t*-test was used to compare average litter sizes between implanted, implant-removed, and control females, and chi-square tests were used to compare stillbirth and infant survival rates. The effects of female age and implant duration on survival rates were tested using log-likelihood ratio tests and logistic regression.[19] A paired *t*-test was used to compare litter sizes in the seven females that reproduced both before and after implantation, and a chi-square test was used to compare infant survival rates before and after implantation.

Table 1 shows the number of animals in the control and implanted group with implants removed and implants assumed expired and the number of females with and without previous reproductive experience. Mean age when placed in breeding situations and mean implantation duration are also shown.

RESULTS

Reversibility of contraception

Nineteen (37%) of the 52 implanted females produced young after implants were removed/expired. However, because females were at risk of reproducing for different lengths of time, results are more appropriately presented as the probability of reproducing with time following implant removal/expiration (Fig. 1). Breeding probability reached a plateau of 50% by 2.5 yr after implant removal/expiration.

The reproductive probabilities of females with implants removed ($n = 21$) and those whose implants remained but were presumed expired ($n = 31$) differed significantly (proportional hazard ratio = 3.78; $P = 0.007$). The proportional hazard ratio indicates that the implant-removed females reproduced at about four times the rate of implant-expired females (Fig. 1). Females placed in breeding situations immediately after MGA implant removal reproduced as soon as 5.8 mo and as late as 25.7 mo after implant removal. The probability of reproducing after implant removal was 73% by 2.5 yr (Fig. 1). Animals placed in breeding situations immediately after the assumed expiration of an MGA implant reproduced as soon as 8.0 mo and as late as 56.2 mo after placement. The probability of reproducing by 2.5 yr was 22% in this group (Fig. 1). The females whose placement in a breeding situation was delayed may have bred sooner if they had been presented with the chance.

Given the significance of this difference between implant-removed and implant-expired females, all remaining analyses were performed using only females whose implants had been removed. Within

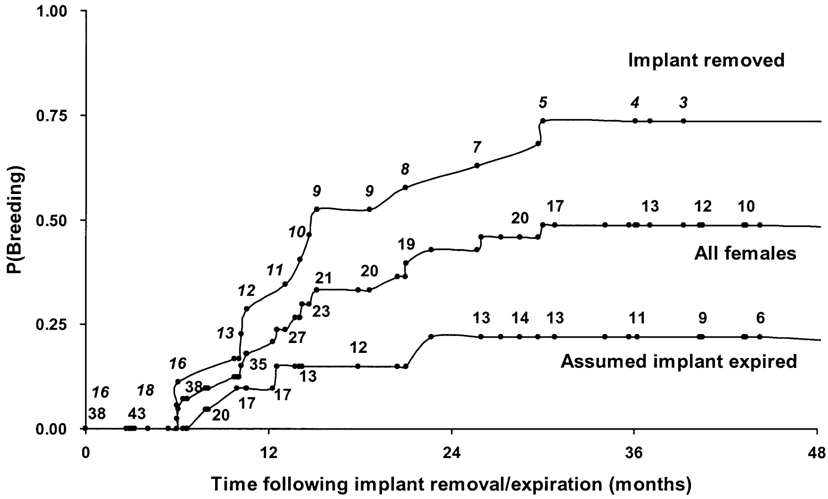

Figure 1. Probability of breeding after implant removal or assumed expiration for three groups of female golden lion tamarins. Numbers above data points represent the number of females still at risk of reproducing at that time point. Dots indicate timing of events (i.e., reproduction, female entering or leaving the study).

this group, there was no difference in probability of breeding regardless of reproductive experience prior to implantation ($P = 0.24$) nor was the probability of breeding affected by the length of time implanted ($P = 0.48$) or the female's age when the implant was removed ($P = 0.69$).

There was no significant difference in the probability of reproduction between the nonimplanted control females and females with implants removed ($P = 0.92$; Fig. 2).

Reproduction in the control group

Probability of breeding in the control group was 43% by 1 yr, 62% by 2 yr, and 67% after 3 yr. There was no effect of proven experience ($P = 0.88$), although this conclusion is suspect because there were only eight females with prior reproductive experience. However, female age significantly affected probability of breeding. Younger females had an overall higher probability than did older females (hazard ratio = 0.99/mo, $P = 0.029$; Fig. 3).

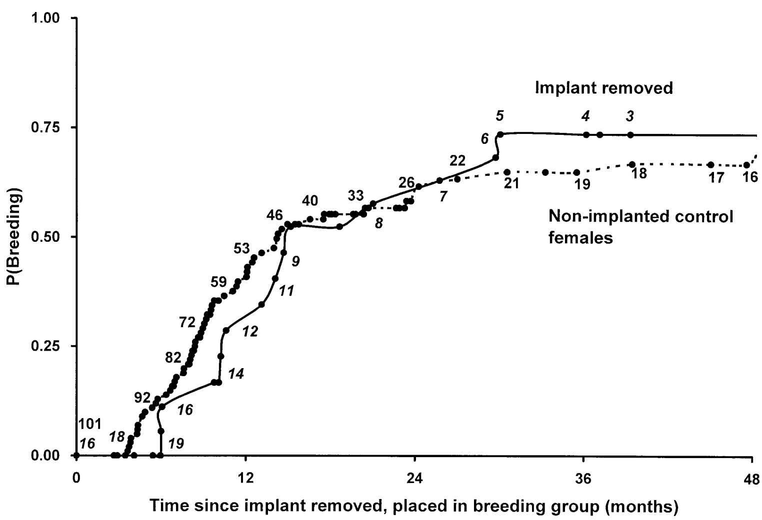

Figure 2. Probability of returning to breeding for female golden lion tamarins that had implants surgically removed compared with nonimplanted control females placed in new breeding situations. Numbers above data points represent the number of females still at risk of reproducing at that time point. Dots indicate timing of events (i.e., reproduction, female entering or leaving the study).

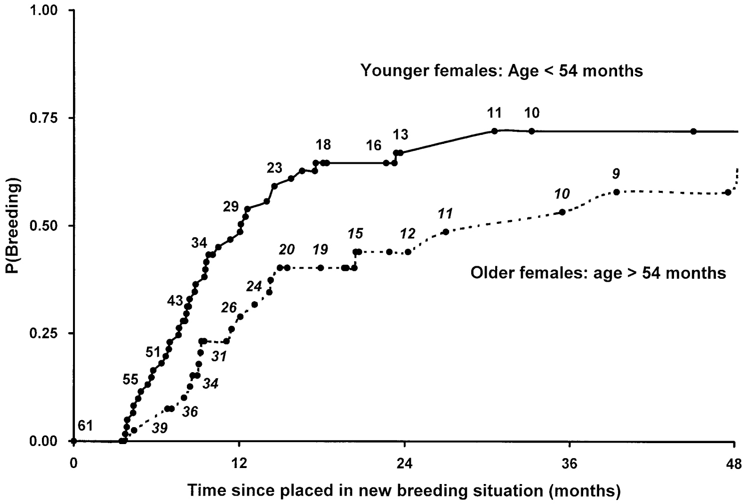

Figure 3. The effect of age on probability of breeding after placed in new breeding situations for nonimplanted control female golden lion tamarins. Numbers above data points represent the number of females still at risk of reproducing at that time point. Dots indicate timing of events (i.e., reproduction, female entering or leaving the study).

On average, each year of age decreased the breeding probability by about 12%. Females younger than 54 mo (the mean age of the control group; Table 1) had 50% reproduction probability by 1 yr of age compared with 30% in older females (≥54 mo). By 2 yr of age, probability of reproduction was 75% for young females compared with only 50% for older females (Fig. 3).

The decrease with age of the probability of reproducing caused concern because the control females were on average almost 2 yr younger ($\bar{x}$ = 54 mo) than the females with implants removed ($\bar{x}$ = 84 mo; Table 1). However, the effect of older age in the implant-removed group would have been to reduce the breeding probability of implant-removed females, which is in the wrong direction to account for any difference. When females younger than 45 mo were dropped from the control group, mean age in the control group (82 mo) was similar to that of the implant-removed group, and using only these data, there was still no significant difference between control and implant-removed females ($P = 0.31$).

Litter size

Thirty-six litters were born to females after implant removal, with a mean (±SE) litter size of 1.89 ± 0.11 (Table 2). The difference between this mean and that for all GLT litters born in captivity to nonimplanted females since 1989 (1.72 ± 0.04, n = 287 litters; Table 2) was not significant ($t = 0.91$, df = 321, $P = 0.36$). However, the average mater-

Table 2. Litter sizes and stillbirth and survival rates in implanted and nonimplanted female golden lion tamarins.

Group	Litter size $\bar{x}$ ± SE (n)	Total no. offspring	No. stillbirths (%)	No. infants surviving 7 days (%)
All nonimplanted females since 1989	1.72 ± 0.04 (287)	514	42 (8.2)	345 (67.1)
Nonimplanted females since 1989 controlled for maternal age	1.78 ± 0.06 (144)	257	24 (9.3)	164 (63.8)
Previously implanted females	1.88 ± 0.10 (51)	96	16 (16.7)	50 (52.1)
Previously implanted females after implants removed	1.89 ± 0.11 (36)	68	10 (14.7)	45 (66.2)
Seven matched implanted females				
Before implanted	1.76 ± 0.08 (28)	53	2 (3.8)	46 (86.8)
After implant removed	2.26 ± 0.09 (23)	48	9 (18.8)	31 (64.6)

nal age for all GLT litters born in captivity since 1989 was significantly lower than that for females with implants removed (76 mo and 105 mo, respectively). By discarding litters born to females younger than 70 mo from the control data for all GLT litters born since 1989, the mean age of the implanted and nonimplanted control females could be equalized (105 mo). Litter size for these age-controlled females was 1.78 ± 0.06 (Table 2), which was still not different than that for the implanted females (t = 0.83, df = 144, P = 0.405). There was no effect of prior breeding experience, age of female, or duration of implant on litter size.

For the seven MGA-implanted females that produced offspring before implantation and after implant removal (Table 2), average litter sizes were 1.76 prior to implantation and 2.26 after implantation. This difference was close to significant (paired $t = -1.71$, df = 6, P = 0.069) but in the wrong direction to indicate any detrimental effect.

Stillbirths

The difference between the 8.2% stillbirth rate in nonimplanted females and the 16.7% rate in previously implanted females (Table 2) was significant (χ^2 = 6.69, df = 1, P = 0.009), whereas the difference between the 9.3% rate in the subset of nonimplanted females controlled for maternal age and the 16.7% rate in previously implanted females approached signficance (χ^2 = 3.74, P = 0.053; Table 2). However, when implanted females whose implants were assumed to have expired were excluded from the analysis, the differences were no longer significant (stillbirth rate of 9.3% for nonimplanted age-conrolled females vs. 14.7% for implant-removed females; χ^2 = 1.65, df = 1, P = 0.198; Table 2). Stillbirth rate was not affected by prior reproductive experience, age of female, or duration of implantation.

In the seven females reproducing both before implantation and after implant removal, the stillbirth rates were significantly lower prior to implantation (3.8% vs. 18.8%; χ^2 = 5.82, P = 0.016; Table 2).

Infant survival

Infants born to all females that had been implanted had a significantly lower first-week survival rate than did infants born to nonimplanted (age-controlled) females (52.1% vs. 63.8%; χ^2 = 4.03, P = 0.045). However, there was no difference between infants born to females whose implants had been removed (66.2%) and those of the nonimplanted age-controlled females (χ^2 = 0.13, P = 0.72).

In the seven females reproducing both before implantation and after implant removal, survival rate for infants born after implant removal (64.6%) was also significantly lower than that for infants born before implantation (86.8%; χ^2 = 6.86, P = 0.009; Table 2). Infant survival for these seven females prior to implantation was significantly higher than that for all nonimplanted females (67.1%; χ^2 = 8.69, df = 1, P = 0.003), and infant survival after implantation was not different than that of nonimplanted females (χ^2 = 0.13, P = 0.72; Table 2).

DISCUSSION

With this analysis, we examined how well female GLTs return to reproduction after the implant is removed/expired and whether or not the return to reproduction is affected by prior reproductive experience, age, length of time implanted, and the implant status as removed versus allowed to expire. We also evaluated previously implanted females for such adverse effects as decreased litter size, reduced offspring survival rates, or increased stillbirth rates.

Contraception achieved with MGA implants is successfully reversible in GLTs if the implants are surgically removed. Females with implants removed were able to breed with success rates comparable to those of female GLTs that were never implanted. This finding agrees with those of previous studies, which were based on smaller sample sizes.[2,7]

The reversibility of implants in the GLT contrasts with a relative irreversibility in the closely related GHLT, in which only 28.6% of females reproduced after implant removal.[8] The difference is difficult to explain because the reproductive physiologies of these closely related species are poorly understood. Methodologies in the studies may have differed. We used survival analysis to incorporate data for females exposed to risk of reproduction for differing amounts of time. This approach allowed females that were removed from the study for reasons of death, senescence, etc., to be included only for the time they were at risk of reproducing. Females at risk for only short periods of time contribute relatively little to the analysis. In the other study involving GHLTs, the total percentage of females reproducing was analyzed. Females that may have been exposed to only short periods of reproductive risk would be included as making a contribution equal to that of females followed for much longer periods of time.[8] This approach could have biased the results if females were followed for different amounts of time or were followed for short periods of time. However, GHLTs with implants removed were followed an average of 49.6 mo (10.5–82.9 mo; De Vleeschouwer, pers. comm.), which is probably sufficient time for most of them to resume breeding. Nevertheless, 62% (13/21) of female GLTs (with implants removed) reproduced. This is still more than double the value of 28.6% for reproducing GHLTs. The number of females followed here is also larger than that in the GHLT study (21 GLTs vs. five GHLTs).

One possible explanation for the differences in probability of returning to breeding between GLTs and GHLTs may be differences in size of implants (and therefore MGA dose) for the two species. Initial data suggest that GHLTs may have received larger implants than did GLTs (De Vleeschouwer, pers. comm.), so higher MGA levels may account for the delayed return to reproduction in GHLTs. This possibility is currently under investigation.

GLTs and GHLTs also differ in the effects of implantation on litter size. Although MGA implants had no negative effect on GLT litter size (which tended to increase), GHLT litter size decreased in another study (from 1.6 to 1.3 offspring/litter).[8]

Implantation may affect stillbirth rates in GLTs. Although the stillbirth rates in nonimplanted and implant-removed females were not significantly different (9.3% vs. 14.7%), the differences approached significance. For the seven females evaluated before implantation and after implant removal, there was a significant difference in stillbirth rates before and after. In GHLTs, stillbirth rates were also higher in implant removed/expired females (10% before MGA implantation, 24% after implant removal/expiration), but the differences were not significant (reanalysis of previous data[8]). If stillbirths were due to the temporary residual effects that remain for a short while after implants are removed, then the stillbirth rate would be expected to be highest shortly after implant removal, falling to normal levels over time. If stillbirths were due to longer or permanent effects of implants, then rates would be expected to remain higher than rates for nonimplanted females over time. The pattern of stillbirths over time for implanted females was tested and rates did not decline over time ($P = 0.91$ for the test of constant stillbirth rate relative to time since implant removal).

For infant survival, the effects of implants were more complicated. Compared with nonimplanted females, females with assumed expired implants had a significantly lower infant survival rate, but there was no difference for females whose implants had been removed. In the seven very successful females who bred both before and after carrying MGA implants, the infant survival rate after removal was significantly lower than that before implantation. However the infant survival rate before implantation (86.8%) was much higher than that of nonimplanted females (67.1%), whereas the postimplant survival rate was comparable to that for nonimplanted females (64.6% vs. 67.1%). This difference may reflect inherent bias: females with more infants (due at least in part to higher survival rates) are more likely to require reproductive control through implantation than are females producing offspring that are less likely to survive. The same bias effect can be seen in nonimplanted females: females with the highest infant survival rates in the first half of their reproductive histories show normal survival rates in the second half because infant survival rates are not strongly correlated within females over time. Therefore, the observed difference between preimplant and postimplant survival rates in these seven females may simply be due to this bias and may not reflect any impacts of MGA implantation.

The increased stillbirth rate and the decreased survival rate after implant removal in the seven matched females may also be related to increased litter size, which rose from 1.76 offspring/litter prior to MGA implantation to 2.26 offspring/litter after implant removal. Stillbirth and infant survival rates may be sensitive to litter size; this possible relationship requires more study.

The probability of reproducing was significantly higher in females whose implants were removed than in females whose implants presumably expired in place (75% vs. 30%, respectively, after 3 yr). This difference may be partially explained by the younger average age of females from the implant-removed (8.3 yr) compared with the implant-expired (11.9 yr) group. In the control group, older females had lower breeding probability than young females, with 12% lower probability of breeding for every year difference in age. Using this information from the control group to correct for the age differences between the implant-removed and implant-expired groups yields a proportional hazard ratio of $exp(3.6 \times 0.12) = 1.54$. This ratio translates into an age-corrected probability of breeding for implant-expired females of 49% by 3 yr (0.75/1.54),[11] which although higher than 30% is still far lower than the 75% observed for implant-removed females. Age alone, therefore, cannot account for the observed difference in breeding probability between implant-removed and implant-expired females.

Stillbirth and infant survival rates were also lower in females carrying expired implants than in females whose implants had been removed (Table 2). For example, infant survival was 52.1% for all implanted females but was 66.2% for implant-removed females. Such a difference between rates could reflect long-term residual effects of the expired implant. Either the effective life of the implant is longer than the 2 yr generally assumed in this study or there is substantial variation in the time females need to 'recover' from the effects of the implant. The effective life of implants for GHLTs may be at least 29 mo.[8]

These results suggest that 1) MGA implants are effective contraceptives in GLTs, 2) implants should be surgically removed from females from which subsequent breeding is desired, 3) previously implanted females may have higher stillbirth rates, 4) implants still provide some degree of protection beyond the assumed 2 yr expiration, and 5) up to 30% of females will breed if the implant is not removed, but they may experience higher stillbirth and infant mortality rates.

We also examined the reproductive potential for nonimplanted (i.e., control) females placed in new breeding groups; these findings are important for population management. Younger females were more likely to reproduce more rapidly than were older females; probability of reproducing decreased by 12% for each year of age (Fig. 3). Newly paired or implant-removed GLTs had an approximately 40% chance of reproducing the first year, 57% by the second year, and about 75% by the third year, which suggests that new breeding pairs should probably be given up to 3 yr to test their breeding potential. Furthermore, because 25% of pairs may never reproduce, an extra 33% of pairs need to be established to compensate for this potential reproductive failure.[4]

Although reversibility provides flexibility in contraception,[3,8,9] it may be utilized infrequently. In the present study, only 52 of 130 implanted females were placed in breeding situations after implant removal or assumed expiration. In GHLTs, only seven individuals had implants removed for reproductive purposes.[8] With regard to population management, there are three groups of implanted GLTs: those that we expect to breed in the future; a large portion with average genetic value whose implants will only be reversed if close relatives die; and those that will probably never be bred. The large implanted group with average genetic value provides ''insurance'' against unexpected detrimental population events. However, in the group of GLTs that we expect will never reproduce, implant reversibility is of less concern than the effect of implants on the health of the implanted individual. For this group, permanent safe sterilization, possibly surgical, for females and males, which requires only a single capture/anesthesia event,[10,18] would probably be preferable to repeated doses of contraceptives.

There are clinical health concerns about the use of MGA implants in primates and other species. We could not clinically compare implanted and nonimplanted GLTs in this study. However, studbook necropsy records reveal that among the 130 female GLTs implanted there was one deformed uterus, one uterine tumor, two ovarian cysts, and three other tumors. Among the approximately 1337 female GLTs never implanted, there were two deformed uteri, zero uterine tumors, eight ovarian cysts, and three other tumors. These records are not complete, however; so frequencies could not be reliably determined.

Other species in which contraceptive implants have been used have been examined in more detail. Long-term MGA implantation in wild felids has been associated with some pathologic changes, notably a high prevalence of uterine lesions and cysts.[12,14] In a study of 17 MGA-implanted Goeldi's monkeys, three implanted squirrel monkeys, and four nonimplanted Goeldi's monkeys, researchers concluded that long-term MGA contraception in Goeldi's monkeys will almost certainly result in uterine damage and may result in clinically apparent disease. MGA implants also resulted in less severe uterine lesions in squirrel monkeys.[17] In common marmosets, implanted females gained substantial weight and uteri were moderately enlarged. These changes disappeared rapidly upon implant removal.[15] In GHLTs, medical side effects were infrequent, but the number of females examined to date is small. For three of 39 females surveyed there were comments in medical records relating to minor uterine changes.[8,9] In comparison, there appears to be little evidence currently for major clinical concerns in GLTs.

Although the results of the present study suggest that MGA implants may not be as detrimental to GLTs as to other species, the results from studies on other primates, specifically the closely related GHLT, should not be discounted.[8,9] Many factors (e.g., prior experience, age, characteristics of the mate, and environment) affect reproduction. The small number of females available for these analyses and the nonexperimental conditions of this type of retrospective analysis limit the extent to which the many possible confounding variables can be controlled. To gain a clearer understanding of the clinical effects of MGA implants, ultrasound monitoring should continue for both implanted and nonimplanted female GHLTs and GLTs, and the reproductive organs should be examined upon necropsy in a more systematic way. Hormonal assays could also be conducted after implant removal/expiration to determine the appropriate waiting periods before an animal is returned to the reproducing population.

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LITERATURE CITED

1. Asa, C. S., and I. Porton. 1990. Primate contraception methods in use and in development. Proc. Am. Assoc. Zoo Vet. Annu. Meet. 1990: 263.

2. Asa, C. S., I. Porton, A. M. Baker, and E. D. Plotka 1995. Contraception as a management tool for controlling surplus animals. *In:* Kleiman, D. G., M. E. Allen, K. V. Thompson, and S. Lumpkin (eds.). Wild Mammals in Captivity: Principles and Techniques. Chicago Univ. Press, Chicago, Illinois. Pp. 451–467.

3. Ballou, J. D. 1996. Small population management: contraception of golden lion tamarins. *In:* Cohn, P. N., E. D. Plotka, and U. S. Seal (eds.). Contraception in Wildlife. Edwin Mellen Press, New York, New York. Pp. 349–358.

4. Ballou, J. D., and C. S. Houle. 2000. 1999 International Studbook for Golden Lion Tamarins (*Leontopithecus rosalia*). National Zoological Park, Washington, D.C.

5. Ballou, J. D., D. G. Kleiman, J. J. C. Mallinson, A. B. Rylands, C. Valladares-Padua, and K. Leus. In press. The history and genetic and demographic management of captive lion tamarin populations. *In:* Kleiman, D. G., and A. Rylands (eds.). The Conservation of Lion Tamarins. Smithsonian Institution Press, Washington, D.C.

6. Cleveland, J., and C. T. Snowdon. 1984. Social development during the first 20 weeks in the cotton-top tamarin *Saguinus oedipus oedipus*. Anim. Behav. 32: 432–444.

7. DeMatteo, K. 1997. Association of Zoos and Aquaria Contraception Advisory Group Contraception Report Part I: Primates, 1st ed. St. Louis Zoological Park, St. Louis, Missouri.

8. De Vleeschouwer, K., K. Leus, and L. Van Elsacker. 2000. An evaluation of the suitability of contraceptive methods in golden-headed lion tamarins (*Leontopithecus chrysomelas*), with emphasis on melengestrol acetate (MGA) implants. I. Effectiveness, reversibility and medical side-effects. Anim. Welfare 9: 251–271.

9. De Vleeschouwer, K., L. Van Elsacker, M. Heistermann, and K. Leus. 2000. An evaluation of the suitability of contraceptive methods in golden-headed lion tamarins (*Leontopithecus chrysomelas*), with emphasis on melengestrol acetate (MGA) implants. II. Endocrinological and behavioural effects. Anim. Welfare 9: 385–401.

10. Glatston, A. R. 1998. The control of zoo populations with special reference to primates. Anim. Welfare 7: 269–281.

11. Hosmer, D. W., and S. Lemeshow. 1999. Applied Survival Analysis. John Wiley and Sons, New York, New York.

12. Kazensky, C. A., L. Munson, and U. S. Seal. 1998. The effects of melengestrol acetate on the ovaries of captive wild felids. J. Zoo Wildl. Med. 29: 1–5.

13. Kirkpatrick, J. F., and J. W. Turner, Jr. 1991. Reversible contraception in non-domestic animals. J. Zoo Wildl. Med. 22: 392–408.

14. Kollias, G. V., Jr., M. B. Calderwood Mays, and B. G. Short. 1984. Diabetes mellitus and abdominal adenocarcinoma in a jaguar *Panthera onca* receiving melengestrol acetate. J. Am. Vet. Med. Assoc. 185: 1383–1386.

15. Möhle, U., H. Heistermann, A. Einspanier, and J. K. Hodges. 1999. Efficacy and effects of short- and medium-term contraception in the common marmoset (*Callithrix jacchus*) using melengestrol acetate (MGA) implants. J. Med. Primatol. 28: 6–47.

16. Munson, L., L. M. Harrenstien, C. A. Haslem, and J. E. Stokes. 1995. Update on diseases associated with contraceptive use in zoo animals. Proc. Joint Conf. Am. Assoc. Zoo Vet., Wildl. Dis. Assoc., and Am. Assoc. Wildl. Vet. 1995: 398–399.

17. Murnane, R. D., J. M. Zdziarski, T. F. Walsh, M. Kinsel, T. P. Median, P. Kovarik, M. Briggs, S. A. Raverty, and L. G. Phillips, Jr. 1996. Melengestrol acetate–induced exuberant endometrial decidualization in Goeldi's marmosets (*Callimico goeldii*) and squirrel monkeys (*Saimiri sciureus*). J. Zoo Wildl. Med. 27: 315–325.

18. Sainsbury, A. W. 1997. The humane control of captive marmoset and tamarin populations. Anim. Welfare 6: 231–242.

19. SAS Institute. 1999. SAS/STAT Version 8.00. SAS Institute, Cary, North Carolina.

20. Seal, U. S., R. Barton, L. Mather, C. W. Gray, and E. D. Plotka. 1975. Long-term control of reproduction in female lions *Panthera leo* with implanted contraceptives. Proc Am. Assoc. Zoo Vet. Annu. Meet. 1975: 66–80.

21. Van Elsacker, L., M. Heistermann, J. K. Hodges, A. De Laet, and R. F. Verheyen. 1994. Preliminary results on the evaluation of contraceptive implants in golden-headed lion tamarins, *Leontopithecus chrysomelas*. Neotrop. Primates 2(Suppl.): 30–32.

22. Zimbelman, R. G., J. W. Lauderdale, J. H. Sokolowski, and T. G. Schalk. 1970. Safety toxicity of melengestrol acetate in domestic animals. J. Am. Vet. Med. Assoc. 156: 1211–1212.

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