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Parturition process in an amphibian mammal species: new evidences in South American fur seal (*Arctocephalus australis*)

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Abstract

In mammals, the transition from a terrestrial to an aquatic environment has implied a great number of adaptations. While in terrestrial mammals the presentation of the foetus at birth is typically cephalic, in strictly aquatic mammals as cetaceans and sirenians the presentation of the foetus is mainly breech. The order Pinnipedia is the most recently evolved group of marine mammals and has an amphibian lifestyle. We document, for the first time, the parturition process in the largest breeding colony of the South American fur seal *Arctocephalus australis* in Uruguay and compare our results with the scarce information available for other species. The analysis of the parturition processes shows that the cephalic/breech birth ratio was 1. In this species, the presentation of the foetus did not affect the total duration of the parturition process, but the cephalic presentation implied a significantly lower duration of the stage 1 of birth, a trend that is also observed in other Otariid species. Phylogenetic reconstructions suggest that *O. flavescens* and *E. jubatus* are older than the *Arctocephalus* genus, having their most recent common ancestor dated between 5-5.8 mybp. Within the *Arctocephalus* genus, *A. australis* would be the most recent species (0.7 mybp). In this light, the skewed ratios of breech presentation in older otariids species may suggest a convergent adaptation toward the aquatic life. We hope this finding will promote an increase of studies aiming for a more detailed examination on the

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adaptive processes involved in the selection of both types of fetal presentations, and their potential effect on the survival of the pup.

Keywords
Arctocephalus australis; birth presentation; parturition process

Introduction

Aquatic mammals have gone through a great number of adaptations as a result of their transition from a terrestrial to an aquatic environment (Bartholomew, 1970; Berta et al., 2006). Despite the existence of several groups of aquatic mammals (cetaceans, pinnipeds, sirenians, polar bears and sea otters), each with its own evolutionary history, all of them exhibit several convergences related to morphological and physiological adaptations (Castellini & Castellini, 2004; Berta et al., 2006; Castellini, 2012).

The most recent group of marine mammals to evolve, the order Pinnipedia, has the peculiarity of combining feeding at sea with breeding on land. This feature can be the consequence of the distribution of ancestral pinnipeds in polar and temperate waters where the difficulty of thermoregulation for newborns may have forced their rearing on land (Berta & Sumich, 1999), implying that the strategy of maternal behavior adopted is influenced by the evolutionary history of each family: phocids and otariids (Boyd, 2000).

There are also several theories that try to explain the evolution of maternal behaviour in pinnipeds (Schulz & Bowen, 2005). For example, each family has different maternal care aspects, such as lactation duration, that can be associated to: female body size, the instability of pup rearing substrate, or the location's latitude (Schulz & Bowen, 2005; Wheatley et al., 2006, 2008). However, the characteristics of the parturition process have only been studied in a few species, while in others it is mentioned in passing or simply unknown. Unlike current terrestrial mammals, in which foetus presentation is typically cephalic or in aquatic mammals such as cetaceans and sirenians, which the foetus is mainly breech (Slijper, 1956; Harrison, 1969; Berta et al., 2006), the data available about foetus presentation in pinnipeds are contradictory. Some authors suggest that pups are normally born in a cephalic position (Vaz Ferreira, 1975), or that both cephalic and breech presentations occur with similar frequencies (Harrison, 1969; Bowen, 1991), while still other studies showed a high proportion of breech parturition for some otariids species (i.e., Acevedo et al., 2008). In addition, it has been suggested that foetus presentation in pinnipeds may have little effect on the process of birth (Harrison, 1969), however, the foetus presentation has been shown to influence the duration of birth, at least in two species (e.g., Acevedo et al., 2008; Acevedo & Aguayo-Lobo, 2010).

The South American fur seal *Arctocephalus australis* (Zimmermann, 1783) (=*Arctophoca australis*), is an otariid that breeds along the South American coasts

(Vaz-Ferreira, 1956), being the Uruguayan rookery the largest breeding colony of this species (Páez, 2000). A few days after giving birth to a pup, females enter into postpartum estrous and mate with territorial males (Katz et al., 2013). Gestation and pup rearing lasts between 9 and 12 months, which causes an overlapping of the female's breeding investment (Franco-Trecu, 2005). Although there have been significant recent contributions to the understanding of the population's maternal and reproductive strategies (Franco-Trecu et al., 2010, 2012, 2014), the characteristics of the parturition process still remain unknown. To help understand this process we i) analysed the complete process of parturition (including foetus presentation) of the largest breeding colony of *A. australis* in Uruguay and ii) compared our results with the information available for other species.

Materials and methods

Study site and period

Observations were carried out in Isla de Lobos (35°01′S; 54°52′W), a granite island located 11 km away from Punta del Este in the South Atlantic ocean, which hosts the main *A. australis* Uruguayan colony. The study area is a breeding site where nearly 300 pups are born during December each year (Franco-Trecu, 2005). Observations were performed in December, for five consecutive breeding periods (2006-2010).

Records of the parturition process

Six hours a day (7:00-10:00 and 17:00-20:00), parturition processes were recorded while performing daily behavioural observations. The parturition process was divided in three stages following Acevedo et al. (2008): stage 1, from the appearance of the amnio-allantoid sac (or its rupture previous to birth) to the delivery of the foetus (birth); stage 2, from pup birth to the appearance of the placenta in the vaginal channel; and stage 3, from the appearance of the placenta to its complete expulsion. Observations of the complete birth process (and its different phases) were timed, and the foetus presentations at birth were recorded as either breech or cephalic. Observations of females whose parturition was not observed since its beginning were kept in supplementary records. In those cases, we considered foetus presentation and the duration of only those stages completely recorded. Additionally, information about i) rupture of the amnio-allantoid sac: previous to birth or not and, ii) expulsion of placenta: along with the pup or later, were also recorded.

Observation analysis

As normality and variance homogeneity of data were rejected through Shapiro and Bartlett tests, respectively, non-parametric tests were chosen for data analysis. A Chi-square (χ^2) test was used to assess the putative deviation of the cephalic/breech births ratio. Duration of the parturition process (complete and per

stages) according to presentation of the foetus at birth was assessed using the non-parametric tests Mann-Whitney (U) and Kruskal-Wallis (H). The significance level considered for all tests was 0.05 (Zar, 1999).

Results

Foetus presentation at birth

For the 137 events observed, the cephalic/breech birth ratio was not significantly different from 1:1 (69/68; $\chi^2 = 0.007$, df $= 1$, $P = 0.93$). In these 137 events observed, four pups born breech and one cephalically were stillborn.

Rupture of the amnio-allantoid sac

In 114 events, there were no differences between the frequencies of the rupture of the amnio-allantoid sac, before or after the appearance of the pup in the vagina (59 vs. 55; $\chi^2 = 0.14$, $P = 0.71$). Foetus' presentation at birth was recorded for 111 of these 114 events. Previous rupture of the sac appeared in 60% of the cephalic births and 46% of the breech births. Differences between them were not significant ($\chi^2_{2\times2} = 2.68$, $P = 0.10$).

Duration of the process of parturition

All three stages of parturition process were recorded 66 times (table 1). The duration of the complete process ranged from 8 to 225 min (mean = 56.9 min, CI 95% = 47.1-73.0 min, median = 46.5 min). Cephalic births took from 8 to 139 min ($n = 29$) with a mean duration of 52.2 min (CI 95% = 38.3-66.2) and median of 45 min. Breech births ranged from 10 to 225 min ($n = 37$) with a mean duration of 60.8 min (CI 95% = 45.4-86.9) and median of 50 min. Birth presentation did not influence the duration of the complete parturition process (Mann-Whitney:

Table 1.
Parturition process recorded for the South American fur seal in Isla de Lobos.

Stages	Presentation	n	Average (min)	Median (min)	Range (min)	P
Stage 1	cephalic	45	10.30	7	1-59	<0.05*
	breech	51	34.58	20	2-193	
Stage 2	cephalic	52	13.33	3	0-141	0.32
	breech	51	8.87	2	0-50	
Stage 3	cephalic	43	26.52	11	0-129	0.43
	breech	44	21.93	11	0-240	

Duration of the three stages during the parturition process recorded for the South American fur seal in Isla de Lobos. Only the presentation of the foetus at birth was considered. The asterisk (∗) indicates the significant difference based on the Mann-Whitney U test.

$Z_{adjusted} = 0.74$, $P = 0.45$, $n = 66$), although the average duration of the first stage (birth) was significantly shorter in cephalic births (see table 1).

Discussion

Cephalic and breech births occurred with equal probability at the South American fur seal population we studied. The only previous result regarding cephalic/breech ratio of foetus at birth in this species, is given by Vaz-Ferreira et al. (1981) with only five observations, being three of them cephalic. Our findings are also consistent with the equal cephalic/breech ratios observed for some otariids species such as Hooker's sea lion *Phocarctos hookeri* (Marlow, 1975), New Zealand fur seal *A. forsteri* (McNab & Crawley, 1975) and Steller's sea lion *Eumatopias jubatus* (Sandergren, 1970), even though all three studies were based on scarce observations (usually $n < 30$) and must be taken with caution. In contrast with the last three studies mentioned above, investigations with more observations ($n > 40$) reported a significant ratio skewed towards breech presentation. Such is the case for four species of otariids: *E. jubatus*, *A. forsteri*, and Antarctic fur seal *A. gazella*, for whom over 60% of the reported births were breech presented (Gentry, 1970; Miller, 1971; Crawley & Wilson, 1976; Acevedo et al., 2008), and South American sea lion (*Otaria flavescens*) in which the presence of breech presentation was even higher: 72% (Acevedo & Aguayo-Lobo, 2010). Therefore, differences in the cephalic/breech ratios obtained in our results and those obtained for the four species of otariids already studied, are not an artefact of the number of observations, since all these studies, including those reported by us, consider the highest number of records on foetus presentations for any kind of otariids yet studied.

Shifting from a terrestrial to an aquatic environment has implied a great number of morphological and physiological adaptations along the evolutionary history of marine mammals. These major changes are currently represented in cetaceans and sirenians that evolved from a terrestrial quadruped ancestor to a strictly aquatic life. In an evolutionary point of view, cetaceans and sirenids always have an older origin (∼60 mybp) than pinnipeds (∼35 mybp) (Berta & Adam, 2001; Arnason et al., 2006; Jefferson et al., 2008), and although cetacean and sirenian have separate evolutionary origins, both groups have converged regarding their adaptations to aquatic life, including reorientation of the foetus at birth (Gingerich & Uhen, 1998; Ursing & Arnason, 1998; Jefferson et al., 2008; Gingerich et al., 2009; Gingerich, 2012). In cetaceans the only potential fossil evidence of this process of birth reorientation from a cephalic to a breech presentation, can be found in the evolutionary line from a semi-aquatic protocetid (*Maiacetus inuus*) to the first completely aquatic whales represented by the family Basilosauridae (*Basilosaurius* and *Dorudon*). The former, dated at 47.5 mybp, showed a foetus near term in cephalic orientation, while for the latter, dated at 40-34 mybp, it is suggested that the foetus was breech presented (Gingerich et al., 2009). Based on these dates, the reorientation of the foetus from a cephalic to a breech presentation would have taken about 7.5-13.5 mybp.

Although divergence times among otariids can still be controversial, phylogenetic reconstructions suggest that *O. flavescens* (72% breech) and *E. jubatus* (60% breech) to be older than *Arctocephalus*, with their most recent common ancestor dated between 5 and 5.8 mybp. Within *Arctocephalus*, the Antarctic fur seal (60% breech) would have diverged between 3.1 and 4.1 mybp, the New Zeland fur seal (*A. forsteri*) 1.1 mybp, and the *A. australis* would be the most recent species (0.7 mybp) (Arnason et al., 2006; Higdon et al., 2007; Yonezawa et al., 2009). In this light, the skewed ratios of breech presentation in older otariid species may suggest that convergent evolution has taken place as adaptation to the aquatic life. However, since the evolutionary process from a common ancestor is cumulative, a ratio skewed towards breech presentation should be reflected also in newer species such as *A. australis*. Nevertheless, the influence of habitat, life history, consequences of the polar and temperate distribution and/or intrinsic or extrinsic factors operating on each species, might be determining the strengthening or relaxation of the evolutionary pressure on foetus orientation. This is supported by our finding that the breech orientation seems not to be detrimental for the survival of pups during the birth process. It should also be note that also genetic heritage, fetal, maternal and ovular factors, such as increased and decreased amniotic fluid, increase the frequency of breech presentation (Melchor, 1999; Lanni & Seeds, 2012).

Conversely, the duration of the complete process ranged from 8 to 225 min (mean = 56.9 min), a similar range reported for the same genus, like *A. forsteri* (10-173 min, McNab & Crawley, 1975), *A. gazella* (6-186 min, Acevedo et al., 2008), as well as for different genera such as *P. hookeri* and the Australian sea lion *Neophoca cinerea* with intervals of 22-360 min (Marlow, 1975). As we report here, the birth presentation of the foetus in *A. australis* did not affect the duration of the complete parturition process. However, the birth process (stage 1) was significantly longer for breech births than for cephalic ones (see table 1), a trend that has also been observed for another otariid species (Gentry, 1970; Stirling, 1971; Marlow, 1975; McNab & Crawley, 1975; Odell, 1975; Acevedo et al., 2008; Acevedo & Aguayo-Lobo, 2010). Acevedo et al. (2008), suggested that this difference in duration of the first phase between both presentations could be explained by the effect of friction exerted between the fur of the foetus and the uterus-vaginal wall after the rupture of amnio-allantoid sac during the transit of foetus in breech position to the outside. In addition, the changes in the position of the pectoral flippers can increase the scapular diameter and make the step of expelling the fetus through the uterus-vaginal channel more difficult. In terrestrial mammals, a long first stage of labour appears with foetus in breech presentation, because the buttocks, knees, or feet are poor dilators of the cervix (Stockinger et al., 2011).

Although breech presentation at birth in terrestrial mammals may increase the risk of drowning and/or mechanical injury (Moh et al., 2012), no data are available on potential effects on growth or further survival of pups after birth. In humans, breech foetuses are found to be smaller, with lower birth weights and born about one week earlier than cephalic foetuses (Luterkort et al., 1986). In addition, they

are associated with less coordinated leg movement, resulting in alterations in leg posture, reflexes and walking coordination 12-18 months after birth, because the lower part of the pregnant uterus provides less movement freedom for the fetus than the upper part (Sival et al., 1993).

In summary, i) we documented, for the first time, the full duration of the parturition process in *A. australis*, ii) our results show that breech presentation occurred at a similar frequency as the cephalic one, iii) foetus presentation has a significant effect on the length of the first phase of the birth process, with the breech presentation taking longer than the cephalic one, a trend that is also observed in other Otariid species. Further studies of the birth processes are needed in order to determine the adaptive mechanisms involved in the selection of foetus presentations at birth. We consider that our results are an interesting report, and we hope that this study stimulates a more detailed analysis of the adaptive processes involved in the selection of both types of fetal presentation, and their potential effect on the survival of the pup.

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