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A canine anatomic atlas of embryonic development, based on accurately timed gestational ages and comparative developmental staging.

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Through progress in canine genomics, dogs were found to have advantageous genome structure as well as disease phenotypes that could facilitate the study of human inherited disorders. Gene therapy offers the promise of cures for some inherited disorders, yet such therapy first requires testing in animals. Since canine in vitro fertilization and genome editing are now possible, prenatal gene therapy in canine models is feasible. As therapeutic effects may first be observed during development, there is a need for a canine atlas of development based upon precise timing of gestation and comparative developmental staging. The goal of this project is to produce such an atlas for researchers and clinicians. Gestation was timed from the day of the preovulatory serum luteinizing hormone surge (d0) and concomitant rise in serum progesterone (P4) concentration in the dam. By this method, unassisted parturition occurs at d65+/−2d.1 Embryos were collected from d28-44 gestation in accordance with the National Institutes of Health Guidelines for Vertebrate Animal Research. Sex of embryos was determined by polymerase chain reaction assay (PCR) for canine SRY in genomic DNA. Developmental stages were determined from digital photographs of external morphologic criteria, as in human embryos,2 and from comparative staging of human and mouse embryos.3 The atlas includes digital photographs of external morphology and gross anatomy of internal organs, which are displayed in webpages organized by organ and developmental stage. Photographs are shown for embryos collected at 10 ages between d28-44 of gestation. For example, at d28, canine embryos are developmentally comparable to human Carnegie Stage 15 (CS15). By d44, canine embryos are developmentally older than human CS23. Photographs confirmed that the canine bipotential gonad emerges medially from the mesonephros at d28-29. At this age, the forelimbs and rearlimbs are paddle-shaped. The heart is tubular, but looping to the right. The lungs are two oval buds at the caudal end of the trachea. The stomach is a widening of the foregut, and two oval buds comprising the liver are cranial to the stomach. Similar morphologic criteria are presented for all ages in the canine atlas, which will enable researchers to identify the gestational age and developmental stage of canine embryos from gestational ages d28-44. The atlas also includes all criteria used in this project to developmentally stage canine embryos and to compare canine developmental stages to those of the human and mouse, as well as tables correlating canine developmental stage with gestational age, and the protocol for accurately timing canine gestation based on serum P4 concentrations of the dam. As data becomes available over time, we expect other canine embryonic information to be added, such as photographs of earlier ages and gene expression data for specific organs, such as in situ hybridization studies.


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