Bovine embryo evaluation with machine learning: A tool for the future of assisted reproduction

R. Killingsworth,[1] DVM; M. Rae,[2] BS; C.E. Wells,[3] PhD; C Hayden,[3] MS

[1]Shamrock Veterinary Hospital, Inc., Shamrock, TX 79079
[2]Yellowstone Genetics, Fort Morgan, CO 80701
[3]Emgenisys, Inc., Houston, TX 77002

Introduction

In recent years, the integration of machine learning and computer vision (ML/CV) technologies has significantly advanced assisted reproductive technologies, and more specifically, the field of embryo analysis. In human in vitro fertilization (IVF), ML/CV has been used on time-lapse imaging systems to evaluate embryo morphological features to classify their quality and associated implantation potential. This technology has improved the accuracy and efficiency of embryo grading and selection by evaluating more parameters than the human eye can see under the microscope and removing the subjective nature from human evaluation. However, there has been little progress as it relates to ML/CV in the commercial bovine conventional embryo transfer and IVF industry. Thus, this study aimed to explore the potential of ML/CV automatic stage and grading techniques on bovine embryos. It was hypothesized that the machine learning model would outperform humans with little to no experience and perform equally or greater than humans with moderate or more experience staging and grading bovine embryos.

Materials and methods

A voluntary embryo evaluation survey was administered across social media with respondents to complete embryo stage and quality grade predictions on images of 10 bovine embryos according to the International Embryo Technology Society standards. Demographic data was captured on respondents and results were categorized anonymously. Survey results were categorized by experience level in the following 3 groups: novice (1-5 years), experienced (6-10 years), very experienced (> 10 years). The same images from the survey were subjected to ML/CV deep learning algorithms with predictive capacity for ML classification of embryos according to their developmental stages and quality attributes with the model being trained on over 5,000 videos as evaluated by experienced embryologists. Comparison groups that were subjected to statistical analyses are as follows: Novice, Experienced, Very Experienced and Machine Learning. Survey responses were grouped by experience levels and analyzed with ANOVA and Tukey's HSD using $P < 0.05$ for significance. Chi-Square was used to analyze agreement between embryologists and ML.

Results

A total of 42 respondents completed the survey with the top 3 self-reported demographics to include: veterinarian (45%), embryologist (34%) and academic (21%). Thirteen of 42 (13/42 [31%]) reported to be Novice, 15/42 (38%) reported to be Experienced and 13/42 (31%) reported to be Very Experienced.

When comparing embryo stage evaluations based on embryologist experience level, significant differences were found between experience groups in 6/10 evaluated embryos ($P < 0.05$). Furthermore, it was found only 59.8% of all embryologists agree on the stage of embryos. Agreement was improved in Experienced and Very Experienced embryologists, collectively achieving 74.6% agreement.

When ML learning was used to classify embryo stage, the ML predictions achieved 70% agreement with all respondents. Moreover, the ML achieved 85% agreement with Very Experienced embryologists, indicating no statistical differences between Very Experienced embryologists and the ML assessment ($P = 0.3$).

Only the Very Experienced embryologist group and ML properly identified the Unfertilized Oocyte (UFO) which has 0% likelihood of resulting in pregnancy.

Significance

The results of this analysis illustrated the capability of machine learning models to accurately predict the stage and grade of bovine embryos. The ML assessment performed comparatively to Very Experienced embryologists, and outperformed the stage and grading accuracy of Novice Practitioners, suggesting use of ML to evaluate embryos could benefit Novice embryologists and ET practitioners. This research underscores the transformative impact of incorporating machine learning and computer vision approaches for embryo analysis and offers significant promise for improving the outcomes of bovine embryo transfer procedures in the future.

