Machine learning embryo evaluation reliably predicts embryo stage and morphokinetic activity

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Introduction

The utilization of in vitro fertilization (IVF) and embryo transfer (ET) to accelerate genetic selection of both beef and dairy cattle has experienced a rapid increase of adoption in recent years. However, the industry grapples with a pronounced shortage of skilled practitioner's adept in these specialized procedures, especially laboratory skills including embryo evaluation. The ability to proficiently evaluate embryo quality is arguably one of the most challenging components of IVF and ET and proper selection of healthy embryos for transfer is critical to the success of the ET/IVF procedure. Recent advancements in computerized systems and machine learning (ML) can standardize and automate this evaluation process, oftentimes outperforming the morphological assessment of the practitioner. Practical concerns of utilizing ML/CV to evaluate embryos includes the variation of embryo appearance which can change based on their orientation in the culture dish. Therefore, objectives of this study aim to test the reproducibility of computerized systems and ML results by repeatedly evaluating embryos oriented in changing positions.

Materials and methods

In this longitudinal study, we collected 30 second video data of 62 in vitro produced Holstein embryos during routine ET. First, a 30 second video was captured of each embryo while stationary, followed by another 30 second video after rolling the embryo into a new position. These videos underwent analysis by 2 computerized systems. First, a system was employed to quantify real-time embryo morphokinetic activity frame-by-frame, enabling precise tracking of morphological changes and developmental dynamics. Second, a machine learning model was utilized to predict embryo stage (1-9) based on the captured morphokinetic patterns. The morphokinetic activity analysis and ML prediction of the first video were compared to the that of the second video of the same embryo to assess computerized system and ML consistency. This step aimed to evaluate the reliability of both systems in predicting embryo morphokinetics stage classification. Additionally, the predictions from the computerized ML system were compared to the 1-9 stage classifications assigned by a highly experienced embryologist. This comparison served as a benchmark for evaluating the performance of the automated prediction methods against human expertise. In the morphokinetic analysis, embryo change, as denoted by pixel change, was calculated between every 10 frames, resulting in the 90 frames per embryo video for analysis. ANOVA and Tukey's HSD was used for statistical analysis using $P < 0.05$ for significance. To compare the consistency and repeatability of the ML embryo stage and grade prediction, the percent agreement between the first and second video prediction was determined.

Results

The computer predicted matching embryo stage outcomes in both video 1 and video 2 for 78% of samples. For embryo samples in which the computerized model did not agree, results differed by 1 stage (ex. In video 1, the model predicted the embryo to be stage 7 and in embryo 2, the model predicted the embryo to be stage 6). For embryos with matching stage outcomes, the computerized stage prediction matched with the stage classification of the human embryologist for 90% of samples. For samples which computerized outcomes did not match, at least one of the predictions matched the stage classification of the experienced embryologist. ANOVA showed morphokinetic differences were not significant.

Significance

Results demonstrated consistency between the real-time embryo morphokinetic system and the ML model to predict embryo stage. Both systems exhibited robust performance, as shown by their strong agreement with the assessments made by the experienced embryologist. Overall, this study showcases the effectiveness of utilizing computerized systems for bovine embryo evaluation and supports the use of computerized systems to compliment veterinary embryologists to enhance laboratory skill proficiencies.

