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Review

Culture of bovine embryos in intermediate host oviducts with emphasis on the isolated mouse oviduct

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Abstract

The oviduct provides the optimal environment for the transport of sperm and oocyte at the earliest stages of mammalian embryo development. During the early postfertilization period, several major developmental events occur in the embryo including (i) the first cleavage division, (ii) activation of the embryonic genome, (iii) compaction of the morula, and (iv) formation of the blastocyst. Most of these events are initiated in the oviduct. The absence of assistance from the oviduct may compromise the developmental ability of the cattle embryo under in vitro culture conditions. The oviducts of several mammalian species, including rabbits, cow, sheep (in situ), and mice (organ culture), can sustain early bovine embryos and yield blastocysts of better quality compared with those of culture conditions in vitro, leading to normal pregnancy rates in recipient animals. This review focuses on the use of oviducts in vitro or in vivo as intermediate hosts for postfertilization culture environment of bovine in vitro–produced zygotes with emphasis on the mouse model.

Keywords: Bovine IVP; Embryo quality; Organ culture; Oviduct

Contents

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1. Introduction

In vivo, mammalian oocytes and embryos develop in a complex and dynamic environment. First, in the ovarian follicle, the oocyte grows and matures, achieving full developmental competence; subsequently in the oviduct, the oocyte undergoes fertilization and early embryonic development, and finally in the uterus, the blastocyst forms, hatches from the zona pellucida, elongates, and progressively attaches to the uterine wall.

In the cow, fertilization occurs in the midpoint of the oviduct [1]. First cleavage, to the 2-cell stage, occurs approximately 1 to 2 d after fertilization. Between Days 3 and 4 after fertilization, at the 8- to 16-cell stage, the embryo moves from the oviduct to the uterus [2]. Between Days 5 and 6, the embryo reaches the 16- to 32-cell stage, and the cells begin to form intimate junctions [3], forming a compact ball of cells termed the *morula*. Compaction is a prerequisite to trophectoderm differentiation and is essential for blastocyst formation [4]. At Day 7 to 8, a blastocoelic cavity develops, and the cells of the early blastocyst differentiate into inner cell mass cells, mainly destined to form the fetus, and trophectoderm cells, destined to form the placental tissues. At this stage, the blastocyst comprises about 120 cells with the inner cell mass constituting about 25% and the trophectoderm about 75% of the total cell number.

The first success in the in vitro fertilization of an in vitro–matured bovine oocyte was accomplished with semen capacitated in the oviduct or uterus of cows in estrus or the uterus of a rabbit [5]. The first live calf resulting from in vitro fertilization (IVF), of an ovulated oocyte, was born in 1981 after the transfer of a 4-cell embryo into the oviduct of a recipient cow [6]. Lambert et al. [7] reported the birth of calves after the in vitro fertilization of in vivo–matured oocytes recovered by laparoscopy close to the time of ovulation, and the culture of the resulting embryos in the rabbit oviduct. The first calves born after in vitro maturation and fertilization and subsequent culture in the rabbit oviduct were reported by Hanada et al. [8], and one of the first pregnancies produced entirely from in vitro maturation, fertilization, and culture was reported by Lu et al. [9].

In the past two decades, much research on ruminant embryo production has focused on the fundamental question of why only 30% to 40% of immature oocytes develop to the blastocyst stage and on the issue of blastocyst quality in terms of cryotolerance, gene expression, and ultimately pregnancy rates. Although a certain amount of progress has been made in both areas, the quality of in vitro–produced blastocysts continues to lag behind that of blastocysts produced in vivo. This inferiority of in vitro–produced embryos is manifested in terms of several morphologic parameters and is reflected in several ways, not least of which being the number of in vitro–produced embryos transferred in commercial practice [10]. Studies using the sheep oviduct in situ for the postfertilization culture of in vitro–derived zygotes [11–14] indicated that the key part of the process responsible for suboptimal embryo quality is the period of culture after fertilization. Within in vitro systems, modifications of the embryo culture environment after fertilization can have a profound effect on gene expression in the embryo [14–18] that, in turn, can have serious implications for the normality of the blastocyst.

The oviductal environment can support embryonic growth up to the blastocyst stage across a wide range of species after trans-species transfer. The use of such intermediate hosts for the culture of zygotes fertilized in vitro or in vivo is not a recent phenomenon [19–23], but whereas in the early days it was a necessary means of achieving development before the development of adequate in vitro culture systems [24,25], nowadays such systems are used to produce embryos of superior quality [11–14]. The isolated mouse oviduct (IMO) ex vivo culture system has been successfully used in the in vitro culture of mouse [26,27], rat [28,29], hamster [30], porcine [31,32], and bovine [33–39] embryos from the 1-cell stage to the morula/blastocyst stage. This review focuses on the use of oviducts in vitro or in vivo as intermediate hosts for postfertilization culture environment of bovine in vitro–produced zygotes with emphasis on the mouse model.

2. The oviduct: The physiologic embryo environment

The oviduct provides the environment for the transport and capacitation of the sperm and the transport and fertilization of the mature oocyte [1]. The oviduct, its secretions, and its functions have been reviewed thoroughly [1,40–43].

The composition of oviduct fluid has been well researched [41–48]. Chemical analyses have indicated that oviductal fluid is a complex mixture of constituents derived from the plasma plus some specific proteins formed by the oviductal epithelium [41,49]. Recent studies from Hugentobler et al. [50–52] have measured energy substrates, amino acids, and ion concentration in oviductal fluid collected from heifers in situ at different stages of the estrous cycle. In the cow, oviduct fluid is