A Review on the Third Era of Human Reproduction Ectolife - "Artificial Womb Technology"

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***Abstract*- The field of artificial womb technology has surfaced as a revolutionary and transformative domain within reproductive science. Ectogenesis, an advanced form of premature intensive care, involves raising neonates in an artificial environment. The concept was first introduced by J.B.S. Haldane, a British scientist, in 1924. To achieve ectogenesis for human embryos and foetuses, the development of an artificial uterus becomes necessary. EctoLife, an organization dedicated to reducing human suffering and minimizing the need for caesarean sections, has designed an artificial womb. Instead of the mother undergoing painful bodily processes, EctoLife proposes a simple solution where couples can "give birth" to their child by pressing a button. EctoLife has proudly unveiled the world's first artificial womb facility, offering parents the opportunity to customize their child's traits from a menu of options. This paper establishes the biological perspective of Artificial Womb Technology without delving into the ethical considerations associated with it also this paper will delve into the potential impact of artificial intelligence on artificial womb technology and its prospective uses.**

Keywords: **Ectogenesis, artificial womb technology, artificial intelligence.**

Introduction:

Artificial Amnion and Placenta Technology (AAPT) or artificial womb technology, is an innovative new field of study that could help high-risk pregnant women and provide a better option for prematurely born babies than neonatal intensive care.[1]Two research groups, one coming from Australia and the other from the United States, have just achieved proof of concept in their development of "artificial womb devices," which they hope will transform the care of premature newborns. These tools, such as the biobag and the EVE (Ex-vivo Uterine Environment) platform, are designed to quicken the ectogenesis process so that premature babies can continue to grow.[2] In 1923, during a talk on the artificial womb, English biologist JBS Haldane first suggested the possibility of fertilizing an egg outside the womb.[3] The upcoming generation of laboratory-created "artificial" wombs surpasses conventional techniques in terms of power and capabilities. This technology enables newborns to comprehend language and acquire new words while still in the womb, which was previously inconceivable without undergoing the natural birthing process. Moreover, it empowers parents to address any inherited genetic diseases within their family history, preventing their transmission to future generations and effectively eradicating those diseases from existence.[4]

In 1990, Japanese scientists, including Yoshinori Kuwabara, unveiled a remarkable experiment involving the development of a goat foetus within an artificial rubber womb filled with amniotic fluid. Following a 120-day pregnancy period, the foetus was delivered through a Caesarean section performed by a gynaecologist at Tokyo University's medical school. Subsequently, the newborn was transferred to a rubber womb containing artificial amniotic fluid, where it remained for 17 days before being born, after 17 days baby will deliver.[3]

Functional models like the Children's Hospital of Philadelphia's Extra-uterine Environment for Neonatal Development (EXTEND), Tohoku University's Ex-Vivo Uterine Environment (EVE), and the EctoLife project—the first artificial womb facility in history—are currently included in the technology. On December 9, 2022, a science communicator and filmmaker in Berlin, Germany, introduced this innovative facility.[14] Discussions around who is eligible for access to ectogenesis and why have become quite heated in response to it. Since the first IVF birth occurred in 1978, the requirements for obtaining access to assisted reproductive technology have undergone significant changes. In the 1970s, heterosexual married couples were seen as the ideal family; however, modern viewpoints recognize that people of different backgrounds, sexual orientations, and marital situations can provide supportive homes for their children. In the United Kingdom, assisted reproductive technologies are legally accessible to a wide range of people, not just married heterosexual couples.[15]

About Artificial Womb Technology:

Technological developments have successfully shown that systems enabling ex vivo gestation—also referred to as "artificial womb technology"—are feasible. It's important to remember, though, that this technology does not completely replace the womb with an artificial device. This breakthrough should be better described as "artificial amnion and placenta technology" (AAPT). It is critical to understand that placenta replacement is not a one-size-fits-all solution and should be carefully evaluated.[17]

This innovative method allows for the development of embryos until they are ready for delivery outside of the mother's body. The artificial womb provides a safe and comfortable means of monitoring the baby's growth from conception to birth. It eliminates the risks associated with traditional delivery, such as premature birth resulting from complications like preeclampsia or gestational diabetes. Additionally, it has the potential for cost savings by reducing hospital stays. This groundbreaking technology offers an alternative to adoption for couples who have struggled with infertility after years of unsuccessful attempts to conceive naturally or through assisted reproductive technologies like IVF. By transferring embryos to the artificial womb, they can develop until full term before being joyfully delivered into the arms of loving parents.[4]

The potential achievement of this objective stems from advancements in two broader areas of research. Firstly, progress in in vitro fertilization and related embryo research has extended the duration for which a fertilized egg can be sustained and developed in a laboratory setting. Secondly, advances in medical science aim to rescue premature infants at progressively earlier stages of delivery. The convergence of these two research streams holds the promise of developing artificial wombs capable of complete ectogenesis—enabling the creation of a human child without the necessity for any gestation period within a woman's body.[18]

A Biobag:

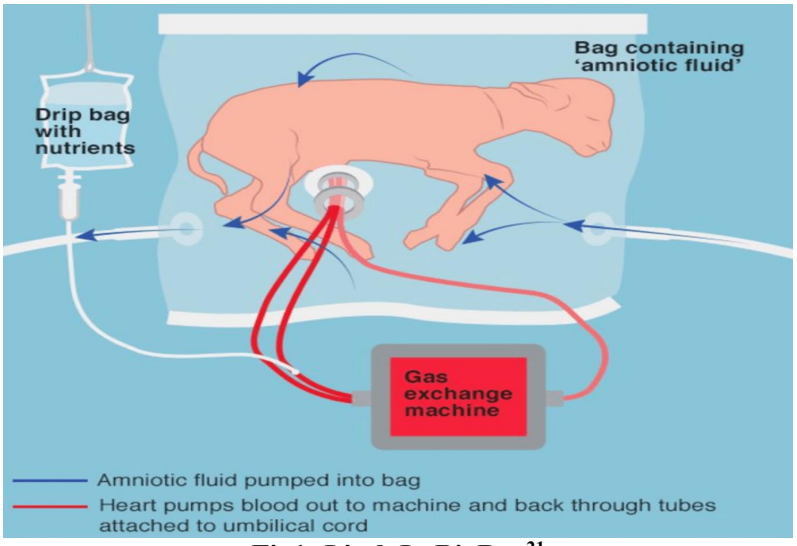

Fig1: Limb In BioBag[21]

The Biobag, described in the journal Nature Communications, utilizes essential components similar to a womb: a transparent plastic bag that protects the foetal lamb like the uterus, an electrolyte solution resembling amniotic fluid, and a mechanism for blood circulation and carbon dioxide-oxygen conversion.[7]

The Biobag is a sterile environment created by a sealed polythene bag containing synthetic amniotic fluid and antibiotics. After birth, the lambs were placed in Biobags and their umbilical cords were connected to a unique pumpless oxygenator. This allowed the lambs' hearts to control blood flow, mimicking the circulation of the fetus and avoiding pressure imbalances. Additionally, the typical alterations that take place when a newborn breathes for the first time are avoided by the closed fluid environment. An important accomplishment of this innovation is that the fetal circulation is retained.[19]

The Biobag, as highlighted by researchers, allows the fetus to continue gestation, treating the baby as an unborn fetus rather than merely assisting preterm functions like an incubator. The Artificial Womb (AW) aims to aid extremely premature babies during the critical 24 to 28 weeks, providing a more natural environment similar to a natural womb.[20]

Working Of Artificial Womb:

Low-resistance hollow-fiber oxygenator technology is used in the artificial womb. It has a streamlined pumpless circuit with small priming volumes and surface area. It is propelled by the pressure gradient and natural cardiac output. The oxygenator (Maquet Quadrox-ID Paediatric Oxygenator) used has a priming volume of less than 80 mL and almost little resistance. Blood is moved from the arteries to the oxygenator and back again via short portions of tubing. Anti-

thrombogenic compounds are coated on all internal surfaces, tubing, and cannulas to ensure biocompatibility and prevent blood clotting.[11]

The growing chamber recreates the uterus's natural environment, maintaining optimal temperature, humidity, and supplying essential oxygen and nutrients to the developing foetus. A continuous flow of oxygen-rich blood is provided from a separate container until delivery. Amniotic fluid, which surrounds the foetus in the mother's womb, is present in the Artificial Womb, containing vital nutrients for the baby's development. The Growth Chamber is equipped with advanced AI-powered sensors that monitor the foetus' vital signs.[8]

In initial tests, the artificial womb (AW) effectively sustained preterm lamb "foetuses" for 4 weeks, replicating the uterine environment. These lambs, delivered at 24 weeks, showed developmental comparability to human preterm infants. All individuals survived the incubation period, leading to global headlines celebrating the achievement by the Philadelphia-based team.[6]

constructed a pumpless oxygenator system that was encased in a circuit that mimicked the conditions of amniotic fluid and connected to a lamb fetus through an umbilical cord interface. Premature lambs can survive for up to four weeks; they are the same as extremely premature human infants. The fetal circulation, proper blood gas levels, and steady hemodynamics are all maintained by the system. Lambs that receive the right nourishment show appropriate growth, lung maturation, and brain development.[16]

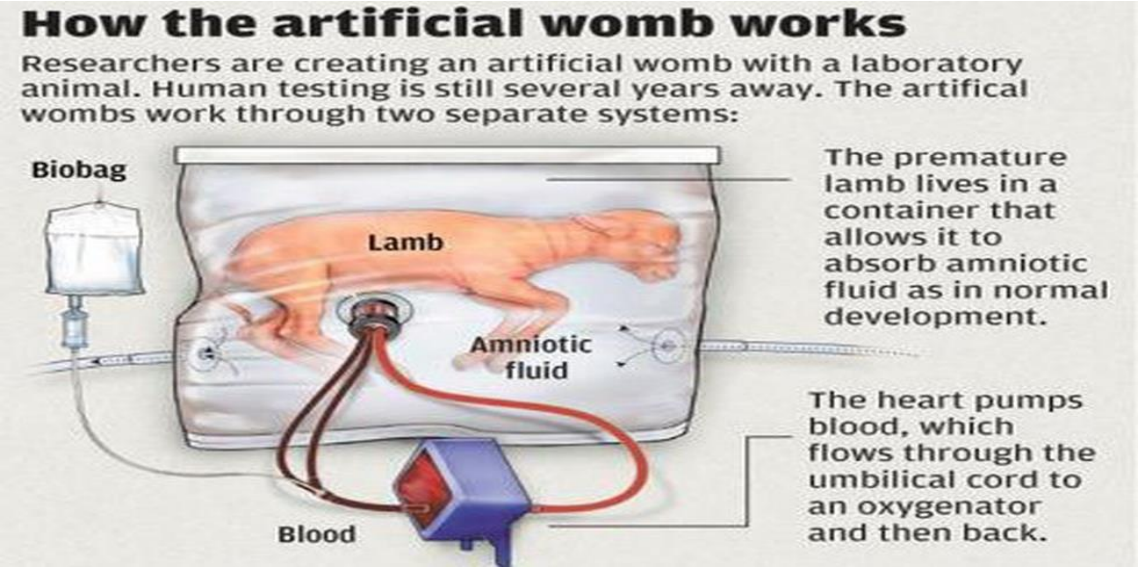

Fig2: Working Of Artificial Womb[22]

Artificial Intelligence's Potential to Revolutionize Artificial Womb Technology:

A specific type of artificial intelligence (AI) called Artificial Womb Technology (AWT) makes it possible for preterm newborns to develop outside of their mothers' wombs through a process called ectogenesis.[20]

Artificial Intelligence holds great potential to propel the advancement of artificial reproductive technologies. The revolutionary concept of ectogenesis, or artificial wombs, has the potential to change our understanding of pregnancy and childbirth. Artificial intelligence (AI) can be utilised to better comprehend and regulate the intricate biological procedures required to provide an environment conducive to foetal development outside of a woman's body.[4]

Through oocyte or embryo scoring and selection, artificial intelligence techniques may be able to assist embryologists in increasing the success rates of in vitro fertilization. To improve manual selection, for example, an image-based pattern recognition system has been created to identify embryos. In other research, intelligent decision support systems assessing patient clinical data and embryo morphology have been introduced for IVF treatment.[10]

Premature Births And C-Sections: How Artificial Womb Technology Will Eliminate Them:

Premature births and C-sections are two of the most frequent medical procedures today. In the near future, these procedures might become obsolete. A foetus' ability to develop outside of the womb will one day be assisted by ultrasound waves. The technology gives pregnant women more control over their own health care decisions by enabling them to monitor their baby's growth without having to rely solely on doctor visits or hospital stays, thereby preventing premature deliveries and reducing the need for caesarean sections for delivery. Technology has many advantages, including lowering the risks of premature birth and C-sections while giving mothers more control over their pregnancies and a sense of security. We will eventually reach a time when premature births and C-sections will only be distant memories thanks to new, innovative technology, which will undoubtedly have a significant impact on maternal health care outcomes globally.[4]

Discussion:
The introduction of AAPT could offer a positive option for individuals seeking to reproduce but prefer not to carry a pregnancy to full term. This may benefit those informed of potential dangers in their pregnancy, those with challenging past pregnancies or births, individuals experiencing difficult pregnancy symptoms, or those who simply do not enjoy the physical impact of pregnancy on their bodies.[13]

Potential uses of ectogenesis:
1. Ectogenesis in neonatal care: reducing health risks and increasing survival for extremely premature infants.
2. Improving the environment surrounding the fetus and developing fetal medicine.
3. Facilitating biological parenthood.
4. Advancing the potential for equality and freedom.
5. Social repercussions: fetal termination, viability, and abortion.
6. Psychological aspects: how ectogenesis affects parents and children.
7. Future outlook: safety, animal trials, human experimentation, and subsequent assessment.[12]

Downsides of ectogenesis:
1. Ethical concerns surround artificial wombs, viewed by some as usurping the divine role of creating life.
2. The process is seen as a deviation from the natural order, working against the inherent system of life creation.
3. Birth through artificial wombs may impact a child's psychological health due to the absence of a natural maternal connection during pregnancy, potentially leading to feelings of isolation.
4. Infants born through artificial wombs face an increased risk of premature birth, associated with health issues such as respiratory distress, brain damage, and developmental delays.
5. The high cost of developing and using artificial wombs may limit accessibility, potentially exacerbating societal inequalities.
6. In a patriarchal context, the technology could diminish the societal status of women, as motherhood is often integral to their recognition and respect.
7. If the right to become a mother is technologically altered, it could undermine the progress women have made in the fight for their rights over the years.[9]

Starting with AWF, the first artificial womb facility, runs entirely on renewable energy. It gives infertile couples a chance to conceive and become biological parents; women who have had their uteruses removed because of cancer or other issues stand to gain the most from this.[5]

Conclusion:
In summary, premature deliveries pose a significant challenge for numerous expectant mothers. Therefore, the discussed Artificial Womb Technology (AWT) appears to have substantial potential in mitigating neonatal morbidity by aiding the development of newborns outside the uterus. A higher-order pregnancy, involving twins, triplets, or more, results from the implantation of multiple embryos in the uterus. The rise in multiple pregnancies is attributed to increased use of in vitro fertilization (IVF). In such cases, women opt for ex-utero gestation by placing extra embryos in a bio bag, highlighting the significant role of artificial womb technology (AWT) in managing high-order pregnancies.
In conclusion, artificial womb technology shows promise in transforming perinatal care by mimicking the womb environment for premature infants, innovation may offer an alternative to traditional interventions, potentially reducing premature births and minimizing the need for invasive procedures like C-sections. While the benefits are significant, ethical, regulatory, and long-term considerations demand thorough exploration. Despite challenges, the trajectory of this technology suggests a future impact on maternal and infant health. Ongoing research, interdisciplinary collaboration, and ethical scrutiny are crucial as we navigate this transformative frontier in reproductive medicine.
Artificial Intelligence (AI) plays a crucial role in the advancement of artificial womb technology, offering solutions to low-population countries by enabling efficient lab-based reproduction. The integration of AI algorithms, including machine learning and natural language processing, allows medical professionals to collect patient data, aiding decision-making in managing pregnancy complications within artificial wombs. AI facilitates real-time monitoring of fetal development, enabling proactive intervention and addressing health issues before birth. This transformative technology not only holds significant medical promise but also presents unprecedented social and environmental advantages, marking a pivotal shift from science fiction to tangible reality.

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