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The Prospects and Ethical Controversies of Artificial Womb Technology: A Case Study of China

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Abstract: ***As a disruptive reproductive technology, artificial wombs not only hold tremendous potential for improving the survival rates of premature infants and optimizing the management of high-risk pregnancies, but also raise profound and complex ethical challenges. This paper focuses on the Chinese context, exploring the future applications and potential controversies of this technology through the lens of moral imagination, and along two developmental trajectories: partial ectogenesis and complete ectogenesis. Artificial wombs may significantly improve treatment outcomes for extremely premature infants and high-risk pregnant women, expand reproductive autonomy, promote gender equality, and offer solutions to ethical dilemmas associated with surrogacy. However, the technology may also disrupt traditional Chinese family structures, intensify tensions between fetal right to life and maternal autonomy, and heighten risks of reproductive coercion and technological misuse. Drawing on Hans Jonas's ethics of responsibility, this paper advocates for anticipatory governance that promotes technological innovation while establishing inclusive ethical deliberation mechanisms. The goal is to strike a balance between technological advancement and social ethics. This study offers a forward-looking ethical framework for navigating artificial womb technology in China.***

Keywords: Artificial womb, Ethical controversy, Chinese context, Technological governance**.**

1. Introduction

Artificial womb technology (AWT) represents an emerging interdisciplinary innovation that integrates neonatal intensive care, prenatal intervention, and assisted reproductive technologies. Its primary aim is to support the continued development of premature fetuses outside the maternal body by replicating the physiological conditions of the human uterus and placental functions. In the future, this technology may be further integrated with in vitro fertilization (IVF), prenatal screening, and related technologies, ultimately extending toward the possibility of complete ectogenesis.

Broadly defined, AWT encompasses key components such as artificial placentas and consist of subsystems including fluid-filled biobags, oxygenation systems, and nutrient delivery mechanisms. Among these, the most critical technological modules include the biobag that simulates the uterine environment, artificial amniotic fluid, extracorporeal membrane oxygenation (ECMO), and fetal monitoring systems [1].

At present, research teams worldwide have made preliminary progress in areas such as artificial amniotic fluid exchange and animal-based experimental models [1,2,3]. Notably, the EXTEND system developed by a medical research team in Philadelphia, USA, comprises three core components: a pumpless arteriovenous circuit, a continuously circulating closed fluid environment, and a novel umbilical vascular interface. This system successfully supported extremely premature lambs for up to four weeks with normal development outside the maternal body [4]. The biobag, designed to closely mimic the intrauterine environment, targets clinical use for neonates born at 23 to 25 weeks of gestation, aiming at significantly reduce mortality and morbidity in this vulnerable population while improving long-term health outcomes.

The EVE system, jointly developed by research teams in Perth, Australia, and Sendai, Japan, has undergone multiple rounds of optimization. It employs a pumpless arteriovenous circuit (via umbilical cannulation), a low-resistance oxygenator, and a fully immersive sterile fluid environment, successfully sustaining lambs equivalent to 22–25 weeks of human gestation for 14 days [5].

The ECLS system from the University of Michigan utilizes a pump-driven veno-venous extracorporeal life support mechanism. Through cannulation of the carotid artery and umbilical vein, combined with liquid immersion to replicate intrauterine conditions, the system enables effective gas exchange without mechanical ventilation, supporting lambs at the equivalent of 24–26 weeks of human gestation for 7 days [6].

At the University of Barcelona, researchers have achieved similar breakthroughs by transferring fetal lambs into an artificial placental system through cannulation, using an arteriovenous extracorporeal circulation (EC) system to create a semi-closed support environment. This system sustained fetuses at approximately 24 weeks of gestation for up to 7 days [7].

In Europe, the Perinatal Life Support (PLS) consortium, led by Eindhoven University of Technology in the Netherlands, is actively advancing AWT. The consortium views this innovation as a crucial means of improving preterm infant survival and envisions it as a transformative direction for future neonatal intensive care [8].

In China, a research team at the First Affiliated Hospital of Zhengzhou University successfully conducted the country's first AWT experiment in 2020. By implementing umbilical arteriovenous cannulation, the team maintained a premature lamb in an AWT environment for 90 minutes without ECMO support. This marked a significant milestone in demonstrating the feasibility of non-ECMO-based oxygenation systems in animal models, potentially replacing ECMO through

alternative biological mechanisms [9].

Although current research efforts overwhelmingly frame artificial wombs as a therapeutic intervention to improve the survival and quality of life of extremely premature infants—limited to partial ectogenesis—the prospect of advancing toward complete ectogenesis is increasingly plausible. Continuous progress in assisted reproductive technologies, evolving social-ethical perceptions, and relaxed regulatory constraints on human embryo research, the 2021 ISSCR guidelines lifting the traditional "14-day rule" and allowing extended in vitro culture under regulatory approval without a fixed upper limit [10], all suggest that the realization of complete extracorporeal gestation may be within reach in the foreseeable future.

2. Multidimensional Imaginations of AWT Applications in China

In 2023, a public poll conducted on China's social media platform Weibo asked whether users supported the promotion of AWT. The results showed that 75% of respondents expressed support, citing benefits such as saving premature infants and alleviating the pain of childbirth, while approximately 9% opposed the technology due to ethical concerns [11]. Ethical issues lie at the core of the controversies surrounding disruptive reproductive technologies like AWT. As Moore's Law metaphorically suggests, the greater the transformative impact of a technology on society, the more complex the ethical challenges it tends to generate.

Given the inherent uncertainty of emerging technologies, an increasing number of scholars and policymakers are shifting away from traditional reactive governance models toward more anticipatory approaches to ethical assessment. Rather than waiting for problems to arise post-deployment, anticipatory ethical governance emphasizes proactive imagination of potential consequences, using tools like moral imagination to evaluate risks and implications in advance. This has become a significant direction in contemporary techno-ethical research.

The American pragmatist philosopher John Dewey provided a theoretical foundation for this method, emphasizing moral imagination as a key faculty for navigating complex social changes induced by innovation. Dewey defined moral imagination as the ability to "concretely perceive what is before us in light of what could be" [12], grounded in two key dimensions:

1) Empathic projection—the ability to place oneself in others' positions to grasp their desires, interests, and fears; and

2) Creative exploration of possibilities—the capacity to envisage different scenarios within specific contexts [12].

Chinese ethicist He Huaihong echoes this view, emphasizing that modern ethical inquiry should cultivate a sense of anticipation, combining empathy with a forward-looking vision. He argues that ethical reasoning must enhance its ability to predict the consequences of actions, and must develop dual imaginative capacities: one for understanding others' motivations and one for projecting future outcomes [13].

This study focuses on mainland China and adopts the method of moral imagination to explore the possible developmental trajectories of AWT. It specifically examines the potential ethical challenges at both the partial ectogenesis and complete ectogenesis stages. By constructing a multidimensional ethical forecasting framework, the study aims to support more systematic and responsible governance of this disruptive reproductive innovation.

2.1 Advantages and Prospects of "partial ectogenesis" AWT

As one of the most populous countries in the world, China has long prioritized maternal and child health in its public health agenda. In recent years, advancements in medical technology have led to a steady decline in both neonatal and maternal mortality rates. The *Healthy China Action Plan (2019–2030)* sets clear targets: by 2022 and 2030, the maternal mortality rate should be reduced to 18 per 100,000 and 12 per 100,000, respectively, while the infant mortality rate should fall to 7.5‰ and 5‰ or lower [14].

At the stage of partial ectogenesis, AWT is not only expected to improve the survival rate and quality of life for extremely premature infants, but also to enable independent treatment of mother and fetus after separation—eliminating the need to balance competing health priorities between the two [15]. The following sections explore the potential benefits of this technology from the perspectives of both preterm infants and pregnant women.

2.1.1 Enhancing the treatment of preterm infants

The World Health Organization (WHO) defines preterm birth as childbirth occurring before 37 weeks of gestation, with extremely preterm infants classified as those born before 28 weeks [16]. Prematurity remains one of the leading causes of death among children under the age of five worldwide. According to a 2014 global assessment, approximately 15 million preterm infants are born each year, with 1.2 million of them in China [17]. As of 2018, China's neonatal mortality rate had declined to 3.9 per 1,000 live births [18]. However, when compared to high-income countries like the United States and Australia, China still faces significant challenges in managing extremely preterm infants.

While the development of perinatal medicine and neonatal intensive care units (NICU) has greatly improved the survival of infants born between 26 and 28 weeks—now approaching survival rates in developed countries [19]—there remains a lack of unified treatment protocols and clinical guidelines for infants born at even earlier gestational ages. There is an urgent need to update and standardize strategies for the prevention and treatment of extreme prematurity.

Despite its life-saving benefits, NICU care is not without drawbacks. Premature infants exposed to bright lights, loud noises, pharmacological additives, and other stimuli outside the maternal womb may experience adverse neurodevelopmental effects or long-term complications [20].

In contrast, AWT can simulate the intrauterine environment, significantly reducing the need for mechanical ventilation and lowering the risk of bronchopulmonary dysplasia (BPD) [21]. Additionally, the acoustics of NICU—characterized by high-frequency alarms and mechanical noise—may disrupt auditory and language development in preterm infants [22, 23], whereas the "immersive" and quiet environment of an AWT supports more favorable neurological outcomes.

Most crucially, in cases where placental insufficiency or intrauterine surgical complications necessitate premature delivery, AWT offers a transitional platform for gestational continuation. By transferring the fetus to an artificial womb, development can proceed ex utero, potentially surpassing traditional viability thresholds and offering a new pathway from marginal survival to healthy development [18].

Moreover, AWT serves as valuable experimental models for investigating the physiology of fetal development. They enable researchers to examine the roles of the placenta, maternal hormones, and growth factors, as well as the pathophysiology of abnormal conditions such as fetal hypoxia. AWT may also offer new interventions for fetal growth restriction caused by placental dysfunction, or allow for early surgical correction of congenital cardiac, pulmonary, or diaphragmatic defects prior to mechanical ventilation [26].

2.1.2 Optimizing the management of high-risk pregnancies

From the perspective of maternal health, AWT holds the potential to become a strategic intervention for managing high-risk pregnancies. According to United Nations data, China's maternal mortality rate has dropped significantly—from 1,500 per 100,000 live births in 1949 to 17.8 per 100,000 in 2019. While this marks substantial progress, a notable gap remains compared to high-income countries. The *Healthy China 2030* initiative aims to further reduce this rate to below 12 per 100,000 [24]. Reducing maternal mortality and managing high-risk pregnancies remain among the core objectives of China's national health strategy.

High-risk pregnancies are typically associated with complications such as gestational bleeding, hypertensive disorders, heart disease, kidney disease, and other comorbidities [25]. In many cases, conventional medical responses involve early termination of pregnancy to protect the mother's health. However, in real-world settings, emotional and ethical concerns often complicate the decision-making process, leading to delays that may forfeit optimal treatment windows.

AWT offers a potential "win–win" solution for such patients. It enables the early termination of intrauterine pregnancy to safeguard maternal health while sustaining fetal development ex utero, thereby easing the psychological burden associated with fetal outcomes. More importantly, artificial wombs provide an innovative research platform for studying placental function, maternal-fetal hormonal interactions, and the mechanisms of fetal development. For instance, it becomes possible to simulate placental insufficiency and investigate interventions that may reverse fetal growth restriction, or to perform prenatal procedures in cases of severe cardiopulmonary malformations, all within a controlled ex utero environment [26].

2.2 Ethical Advantages and Social Prospects of "complete ectogenesis" AWT

Compared to the technological configuration at the "partial ectogenesis" stage, artificial womb technology at the "complete ectogenesis" stage demonstrates more profound impacts and developmental potential in terms of reproductive autonomy, social structural transformation, and ethical justice.

2.2.1 Expanding reproductive autonomy

Reproductive autonomy is a fundamental component of basic human rights. However, in practice, a large number of individuals in China facing infertility are unable to fully exercise this right. According to national reproductive health surveys, the prevalence of infertility in China increased from 11.9% in 2007 to 15.5% in 2010 [19], with the trend continuing upward. These individuals not only face significant physical and financial burdens, but also suffer under the weight of traditional pronatalist values, which imposses intense social and psychological pressure.

The development of complete ectogenetic AWT offers an unprecedented solution to these challenges. By decoupling reproduction from the biological limitations of the female body, it allows women with severe reproductive impairments to have genetically related offspring, fulfilling deeply rooted cultural expectations surrounding bloodline continuity in Chinese society. Combined with supporting technologies such as egg cryopreservation and sperm banks, artificial wombs also loosen traditional constraints on reproductive age and timing. This enables younger individuals to plan reproduction more flexibly, while also offering grieving families—such as those who have lost their only child—a pathway to rebuilding familial structures.

Moreover, AWT holds the potential to liberate reproduction from conventional heterosexual marriage, providing equal reproductive opportunities to same-sex couples, single individuals, and others who fall outside of traditional family norms. In doing so, it reflects a broader ethical inclusivity and social progress, highlighting the technology's transformative power not only in medicine but also in challenging structural inequalities in reproduction.

2.2.2 Promoting gender equality

With the steady rise in women's educational attainment and labor force participation in China, women's roles in the workplace have become a crucial driver of social and economic development. Recent data show that China's female labor force participation rate has reached 64%, placing it among the highest in Asia [27]. However, the unequal distribution of reproductive responsibilities continues to result in significant "motherhood penalties" for women, including career interruptions, limited promotion opportunities, and decreased income [28]. In contrast, men rarely bear such structural costs, further entrenching gender inequality in both workplace and family life.

American scholar Shulamith Firestone has argued that complete ectogenetic AWT could liberate women from the "biological burden of reproduction" [29]. Through this technology, women would no longer have to endure the physical demands and time constraints associated with pregnancy, childbirth, and postpartum recovery. Not only would this reduce or even eliminate career disruptions due to childbirth, but it would also alleviate the psychological stress caused by reproductive challenges. This shift could encourage redistribution of childcare responsibilities within families and promote greater gender equity in the labor market. In the long term, AWT may provide a structural and technological foundation for achieving substantive gender equality in society.

2.2.3 Ending surrogacy exploitation

While overall fertility intentions in China have declined in recent years, certain populations facing infertility due to illness or marital structures continue to express a strong desire for genetically related children. In the absence of legal and accessible alternatives, some individuals have turned to surrogacy as a means of achieving biological parenthood. However, surrogacy remains explicitly prohibited in China, and lax enforcement has allowed a gray market to persist, rife with unregulated commercial activity and ethical concerns [30].

Surrogacy raises serious ethical issues, particularly concerning the bodily autonomy and dignity of surrogate mothers. From a Kantian ethical perspective, commercial surrogacy violates the principle that humans should be treated as ends in themselves, not as means to an end. It commodifies reproductive labor and instrumentalizes women's bodies, leading to an inherent conflict with the concept of human dignity. In commercial arrangements, intended parents benefit from the arrangement, while surrogate mothers often receive limited compensation in exchange for substantial physical, psychological, and social risks. This incommensurability of value exchange constitutes a profound form of exploitation.

Complete ectogenetic AWT provides a non-exploitative and non-intermediated alternative by eliminating the need for a surrogate body, thus enabling individuals who cannot carry a pregnancy to realize their reproductive goals ethically. From a regulatory perspective, such technology could help curb illegal surrogacy practices and foster the legal and institutional development of reproductive governance in China. By replacing ethically problematic reproductive arrangements, AWT may contribute to a more just and transparent reproductive landscape.

3.1 The Transformation and Deconstruction of Traditional Chinese Family Structures

As a disruptive reproductive technology—especially in its complete ectogenetic form—artificial wombs are poised to profoundly reshape the structure of assisted reproduction in China and challenge deeply embedded cultural values and moral norms. One of the most significant areas of ethical tension lies in their potential to transform, and even deconstruct, traditional Chinese family models rooted in Confucian thought.

Classical Confucianism holds that "a man and woman living together is the most important of human relationships" [31]. Marriage between a man and woman, followed by the timely birth and nurturing of children, is seen as the starting point of human civilization. From this marital foundation arises the full spectrum of social relations—between parent and child, ruler and subject, superior and subordinate—all governed by rites and moral principles. Procreation is not merely a function of marriage but also central to familial continuity, ancestral rites, and the inheritance of property in China's patrilineal clan-based tradition. As the ancient saying goes, "There are three ways of being an unfilial son, the worst is to have no heir" [31]. In this context, "carrying on the family line" is not only an act of filial piety but a critical event tied to family prosperity and legacy, deeply ingrained in the Chinese collective consciousness.

Under such an ethical framework, childlessness is often viewed as a family failure, and individuals may be subject to moral condemnation, social stigma, and emotional distress. Today, China has a large population suffering from infertility. These individuals face not only biological and financial challenges, but also persistent psychological and cultural pressures stemming from traditional views on lineage and reproduction. AWT offers these groups a reproductive pathway independent of female gestation, helping to relieve the psychosocial burden of being "childless" and, in a certain sense, providing a technological solution to fulfill the Confucian values of filial piety and lineage continuity.

However, as AWT increasingly substitutes natural pregnancy, the foundational structure of traditional families is undergoing unprecedented transformation. In modern societies where reproductive rights are increasingly recognized as individual rights, single individuals, same-sex couples, and others outside the conventional heterosexual family unit may use donor sperm, eggs, in vitro fertilization (IVF), or stem cell technologies, in combination with artificial wombs, to conceive children. This trend breaks the traditional link between marriage and procreation, leading to the gradual disintegration of the long-held "marriage–procreation unity."

On one hand, artificial wombs enhance the diversity of family structures and enable infertile individuals to establish biological parenthood, thereby reinforcing traditional values such as blood ties and filial duty. On the other hand, the widespread application of this technology means that parent–child relationships may increasingly emerge outside the contexts of marriage and sexual intercourse, giving rise to novel family configurations such as single-parent families, same-sex parenthood, or multi-parent households. These developments challenge the normative foundations of China's traditional family ethics, prompting urgent discussions around parental responsibility, kinship, and legal guardianship.

In fact, the ethical disruption brought by reproductive technologies is not new. IVF was the first to separate sexual intercourse from reproduction, and AWT, as the ultimate form of extra-corporeal gestation, may complete deconstruction of the marriage–sex–reproduction triad. Within this context, China's traditional family ethics face a systematic crisis of relevance, and society must begin rethinking the moral balance between cultural traditions and technological

modernity.

3.2 Ethical Conflict Between Maternal Autonomy and Fetal Right to Life

Globally, there exist significant legal and ethical divergences regarding abortion. In China, abortion is not comprehensively prohibited by law, and the predominant view prioritizes a woman's right to bodily autonomy over the potential life rights attributed to the fetus. This stance reflects a societal tendency in China to regard maternal bodily rights as the central ethical foundation legitimizing abortion.

Philosopher Judith Jarvis Thomson, in her landmark essay "*A Defense of Abortion*," introduced the famous "Violinist" analogy: if one were involuntarily connected to a violinist dependent on their kidney for survival, would they be morally obligated to sustain this connection? Thomson's argument suggests that even if the fetus possesses a right to life, a pregnant woman is under no obligation to maintain the pregnancy at the expense of her own freedom and bodily interests [32]. This perspective emphasizes that in cases of non-consensual pregnancy or when a woman, after due reflection, chooses to terminate the pregnancy, she holds the right to do so without being morally compelled to preserve fetal life.

However, the advent of AWT profoundly challenges this ethical framework. Traditional abortion inherently involves the inseparability of pregnancy termination and fetal death: once removed from the maternal body, the fetus loses viability. With the gradual maturation of complete ectogenetic technologies, fetuses can survive independently outside the womb within artificial environments. This severs the logical equivalence between pregnancy termination and fetal death.

Such a shift confronts the established ethical logic underpinning abortion rights. When technology can sustain fetal life post-uterine removal, abortion can no longer be defined solely as "physiological termination," but must be reconsidered as involving the disposition of fetal life itself. Put simply: under technologically feasible conditions, do Chinese women have the right to terminate the pregnancy or the right to terminate the fetus's life?

More controversially, if a woman chooses abortion but the fetus is transferred to an artificial womb for continued development, profound uncertainties arise regarding the future custody, legal status, and social belonging of that fetus. Would the woman still bear moral or legal parental responsibilities? Or would the fetus become a "technological orphan" under the care of the state, society, or others? China currently lacks clear legal or ethical guidance on these issues.

The maturation of AWT will transform "abortion rights" from a relatively straightforward ethical matter into a complex ethical web involving technological feasibility, legal boundaries, and social responsibilities. Future policy and ethical deliberations must respond to this emerging reality by redefining the relationship and boundary between "pregnancy termination" and "life cessation."

3.3 Ethical Risks of Reproductive Coercion and Technological Misuse

The emergence of artificial womb technology offers unprecedented possibilities for overcoming reproductive barriers and enhancing gestational safety, enabling humanity to further transcend natural limitations in the pursuit of a better life. This technology embodies a high degree of technical rationality and human autonomy. It not only circumvents the physical risks associated with traditional pregnancy but also effectively reduces potential fetal harm caused by maternal behaviors such as alcohol consumption, drug use, and unhealthy dietary habits. Consequently, artificial wombs are likely to be regarded as a "safer" and more "advanced" reproductive alternative.

However, AWT also harbors potential for misuse, potentially giving rise to new forms of reproductive oppression. On one hand, driven by extreme concern for fetal health, relevant governmental authorities may promote or even mandate the use of AWT among specific populations—such as women with high-risk pregnancies, substance abusers, or chronic disease patients—to prevent potential harm to the fetus. On the other hand, employers might implicitly or explicitly pressure employees to forgo natural pregnancy in favor of artificial womb use to ensure labor efficiency and reduce maternity leave costs; insurance companies may impose covert requirements for certain women with health risks to adopt this technology, leveraging its perceived "low-risk" nature in underwriting decisions. Such institutional arrangements, though seemingly motivated by risk management and efficiency, may in fact infringe upon women's reproductive autonomy, forming a novel form of reproductive coercion. From "prohibiting pregnancy" to "prohibiting natural pregnancy," the ethical boundaries underlying technological governance urgently require a clear delineation.

Simultaneously, the risk of technological abuse cannot be overlooked. Some women might choose to abandon natural gestation in favor of artificial wombs for private reasons such as maintaining physical appearance or controlling lifestyle freedom, even when no medical necessity exists. While this phenomenon can be viewed as an extension of personal choice, if the technology becomes further widespread and institutionalized, it may induce more extreme scenarios: confronted with persistently low birth rates and intensifying aging populations, might states or organizations employ artificial wombs for large-scale "production" of new populations as part of demographic strategies? Such dystopian visions have long been foreshadowed in Aldous Huxley's *Brave New World*, where newborns are mass-produced in standardized factories, subjected to uniform education and stratified conditioning, leading ultimately to a society dominated by rigid caste systems and biological determinism.

Moreover, with the synergistic development of gene editing and embryo screening technologies, "eugenic" tendencies surrounding artificial womb usage may escalate. As society increasingly pursues "high-quality" and "high-capacity" fetuses, will functional screening or elimination of "unqualified" embryos become normalized? Should human reproduction follow a path dominated by complete technological rationality, the moral dignity and diversity of

life could face fundamental erosion.

In summary, while AWT expands reproductive freedom, it also conceals profound risks of reproductive instrumentalization, institutionalization, and even nationalization. Preventing its descent into a "technological utopia" or "biological totalitarianism" constitutes a critical challenge that future bioethics and governance frameworks must confront.

3.4 Additional Ethical Controversies

Beyond the aforementioned ethical challenges, the promotion and application of AWT in China involve a series of other pressing ethical controversies that warrant serious attention.

First, there is the issue of fairness in medical resource allocation. China's total medical resources are limited, with longstanding and significant disparities between urban and rural areas as well as across regions. On one hand, AWT could be employed to save extremely premature infants, addressing urgent clinical needs; on the other hand, the technology might be utilized by affluent consumers for non-medical reproductive demands, such as maintaining body shape or lifestyle convenience. Against the backdrop of constrained resources, how should priorities be balanced between "saving lives" and "facilitating reproduction"? Should the technology be primarily allocated to high-risk pregnancy groups and medically underserved regions, or left to serve the personal preferences of economically well-off individuals? These questions concern the justice of public resource distribution and require clear definition and guidance from policymakers.

Second, the moral status of the fetus within the AWT represents another crucial ethical issue. In the "partial ectogenesis" context, the fetus is neither a traditional intrauterine fetus nor fully aligned with the legal definition of a newborn, resulting in a blurred identity. Should such a fetus be entitled to independent personhood, dignity, and rights? How should the scope of medical interventions and boundaries of life protection be delineated? These questions necessitate novel responses and clarifications from ethical and legal disciplines.

Third, the development of AWT may also lead to concerns about the commodification of babies and eugenic tendencies. The high cost of the technology may cause some to view artificial gestation as a means of "customizing" infants. In conjunction with prenatal diagnostic technologies, fetal characteristics such as gender, appearance, intelligence, and health status could become selection criteria, potentially leading to eugenic choices or even deliberate exclusion. When future lives are judged and screened according to technological standards, the inherent dignity and value of individual life face unprecedented challenges.

Moreover, the handling of fetal disabilities or health abnormalities raises important ethical debates. If a fetus within an artificial womb is found to have severe illnesses or malformations during gestation, do responsible parties (such as parents, hospitals, or the government) have the authority to decide on its continuation or termination? This not only concerns bioethical judgments but also implicates the boundaries of technological governance and societal value orientations.

In summary, while AWT demonstrates breakthrough potential in reproductive medicine, the ethical issues it provokes are profound and complex, and cannot be evaded. From women's bodily autonomy to the reshaping of family structures, from the expansion of reproductive freedom to the hidden risks of new social inequalities, these concerns deserve wide attention. Therefore, the clinical application of AWT must be accompanied by concurrent ethical reflection, legal improvement, and institutional development. Broad interdisciplinary and cross-sectoral consultations are essential to construct reasonable ethical and legal frameworks, ensuring that this technology benefits humanity while preventing potential moral crises and social risks.

3. Conclusion

At the current stage, where AWT is rapidly advancing and approaching human clinical trials, proactively imagining and prospectively identifying its potential ethical risks has become an unavoidable social responsibility. Rather than passively responding to issues after the technology matures, it is imperative to initiate ethical governance and institutional design at the nascent stage to realize truly responsible technological development.

German philosopher Hans Jonas proposed the concept of "ethics of responsibility" as early as the 1970s [33], emphasizing that in an era characterized by highly complex and far-reaching technological impacts, technological activities must be guided by responsibility. This responsibility extends beyond managing immediate outcomes to a form of "long-distance responsibility" across time and space — accountable not only to contemporaries but also to the natural environment and the well-being of future generations. Jonas advocates awakening human sensitivity and vigilance toward future risks through his "heuristics of fear," thus upholding prudence, moderation, and reverence in technological applications.

Guided by Jonas's ethics of responsibility, we should cautiously advance AWT with high ethical awareness and institutional constraints. In the "partial ectogenesis" phase, the technology primarily focuses on improving the survival and quality of life of extremely premature infants and optimizing the management of high-risk pregnancies, aligning with the fundamental medical ethical goals of alleviating suffering and saving lives. However, upon entering the "complete ectogenesis" phase, AWT transcends mere medical treatment and profoundly influences systemic transformations in family structure, reproductive concepts, gender equality, and societal ethical boundaries. Therefore, the future advancement of artificial wombs should not be led solely by scientists and engineers but must include joint participation from government regulators, ethics committees, public policymakers, and society at large. By incorporating the "precautionary principle" into technology governance and establishing prudent, transparent, and incremental ethical evaluation mechanisms through multi-stakeholder consultation, we can ensure that AWT is used in a limited, reasonable, and humane manner on the foundation of safety

and human benefit.

In summary, the artificial womb represents not only a breakthrough in reproductive technology but also a profound challenge to human social organization, value systems, and ethical responsibility. Only by holding responsibility as our guiding principle and prudence as our baseline can we steer this technology steadily in a direction that serves the overall interests of humanity.

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