OBSTETRICS AND GYNECOLOGY

Cite as: Archiv EuroMedica. 2025. 15; 3. DOI 10.35630/2025/15/3.311

Received 28 April 2025;
Accepted 04 June 2025;
Published 8 June 2025

ELECTIVE OOCYTE CRYOPRESERVATION IN DELAYED PARENTHOOD: A NARRATIVE REVIEW

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ABSTRACT

Aims: The delay in childbearing and the associated decrease in fertility rates are the most notable trends in the majority of countries nowadays. This review aims to investigate oocyte cryopreservation (OC) as a fertility preservation technique and evaluate its significance in the context of delayed motherhood.

Methods: The literature review was conducted using the PubMed and Google Scholar database. Approximately 40 articles that met the predetermined inclusion criteria were selected for analysis. Publications were published between 2009 and 2025, written in English, focusing on oocyte cryopreservation as a method of elective or medical fertility preservation.

Results: Oocyte cryopreservation shows clinical outcomes comparable to fresh oocytes in IVF, better cost-effectiveness, and no increase in risk of congenital abnormalities. Live birth rates following OC range from 17.6% to 73%, with better results achieved in younger participants. The best outcomes were observed when oocytes were stored at 33 years of age and thawed at 43. Elective OC, compared to OC performed for medical reasons (e.g. oncological diseases) is associated with higher implantation rates. However, OC success rates and cost-effectiveness decline significantly with increasing age, with studies identifying 35 to 38 years as a critical threshold. While OC is generally safe, there remains a risk of complications such as ovarian hyperstimulation syndrome, and advanced maternal age is associated with an increased risk of obstetric complications.

Conclusions: As women increasingly delay motherhood, OC offers an effective strategy to preserve fertility, particularly when performed before age 35. Success rates are strongly age-dependent, and early OC yields outcomes comparable to fresh IVF cycles without added congenital risk. Nevertheless, treatment costs and cycle numbers rise with maternal age, and success is not guaranteed. Broader education, accessibility, and personalized counseling are essential to optimize OC's benefits and address gaps in knowledge regarding long-term outcomes.

Keywords: oocyte cryopreservation, artificial reproductive techniques, fertility, fertility preservation, delayed parenthood, age-related fertility decline

INTRODUCTION

The delay in childbearing and the associated decrease in fertility rates are the most notable trends in Europe. The average age of first-time mothers in the EU has risen over time. In 2013, the mean age of women giving birth to their first child was 28.8 years. This age gradually increased by approximately 0.1 years annually, reaching 29.7 years in 2022. We can also see an increasing percentage of births to mothers over 40. In the EU, this proportion in 2022 was 2.4 times higher than in 2002, rising from 2.5% to 6.0%. During this period, all EU countries saw an increase in the share of live births among women aged 40 and above [1]. Economic and social factors are contributing to a growing and worrisome trend of delayed parenthood in many wealthy nations [2]. Extended education, increased female empowerment, and shifting family dynamics have made early motherhood less appealing under the evolving social, political, and economic circumstances [3]. The crucial stages of progress in education and workplace typically occur during a woman's 20s and 30s—a period that coincides with peak fertility and the onset of its gradual decline [4]. Furthermore, some individuals wish to achieve greater financial security and stability before starting family, especially young adults in their twenties who may face overwhelming student debt. Oocyte freezing gives them time they need to stabilize their finances [5].

AIMS

This review aims to investigate oocyte cryopreservation (OC) as a fertility preservation technique and evaluate its significance in the context of delayed motherhood.

METHODS

This review was based on data sourced from PubMed and Google Scholar. The search was limited to studies between 2009 and 2025. Publications were searched combining the following phrases: „oocyte cryopreservation", "oocyte cryopreservation efficiency", "egg cell freezing and effectiveness", "oocyte cryopreservation ethics". Around 40 publications that met the inclusion criteria were examined and evaluated. Additionally, we used original sources of information from 1984, 1992 and 2002 in order to describe a historical overview.

CONTENT OF THE REVIEW

AGE RELATED FERTILITY DECLINE

Age remains the most critical determinant of a woman's fertility potential. It is well-established that female fertility begins to decline appreciably after the age of 30 [6]. A healthy and well-developed oocyte is essential for achieving successful fertility. The highest number of follicles is present during fetal development in the second trimester, reaching approximately 6 to 7 million primordial follicles [7]. From that stage onward, follicular depletion accelerates progressively, reducing to about 1 million at birth, 25,000 by age 37, and approximately 1,000 by the average age of menopause at 51 [8]. While follicles can be lost through ovulation, the majority are eliminated through atresia prior to reaching the ovulatory stage [9]. Due to both functional and numerical changes in the ovarian oocyte reserve, the declining pool of primordial follicles correlates with a gradual decline in fertility during the reproductive years, which accelerates in the decade preceding menopause [10]. In addition, the reduction in the follicular pool is accompanied by a rising incidence of aneuploidy. Aneuploidy arises when a germ cell contains an abnormal number of chromosomes. The risk of aneuploidy becomes ten times higher after the age of 40 compared to women under 25 [11]. The occurrence of aneuploidy significantly impacts the overall quality of an oocyte. Consequently, aneuploidy affects fertility because it is one of the main causes of infertility and a common cause of early miscarriage [12]. Age-related declines in fertility are caused by a combination of these time-dependent factors. As a result, fertility rates are approximately 15–19% lower in women in their early 30s compared to those in their early 20s, decrease by 26–46% by the late 30s, and drop dramatically—by up to 95% —by the early 40s [13]. While fertility naturally declines with age, other factors may also contribute. A reduction in sexual activity is common as age increases. Additionally, conditions such as tubal disease, leiomyomas, endometriosis, previous tubal and ovarian surgeries, and chemotherapy can further impact fertility in aging individuals [14].

THE EVOLUTION OF OOCYTE CRYOPRESERVATION: FROM EXPERIMENTAL PROCEDURE TO MEDICAL STANDARD.

The year 1984 marked a breakthrough in fertility science with the first successful pregnancy achieved through oocyte donation. This milestone paved the way for an innovative approach to treating infertility, transforming reproductive medicine [15]. Until 2012, OC was limited to investigational protocols. However, that year, the American Society for Reproductive Medicine (ASRM) Practice Committee reclassified oocyte freezing, determining that it was no longer an experimental procedure. Consequently, its routine application was approved for postmenarchal women undergoing gonadotoxic treatments.

While the ASRM Practice Committee recognized the value of OC in the context of medically indicated fertility preservation, it initially refrained from endorsing its use for elective purposes [16]. After six years, in 2017, the ASRM Ethics Committee published a statement declaring that planned OC was ethically acceptable for women

seeking to safeguard against potential infertility caused by reproductive aging or other factors, further legitimizing and reinforcing the practice of elective OC, which had already been in use. Studies conducted on American and New Zealand populations between 2010 and 2016 have demonstrated a sharp increase in the number of OC cycles following the shift in approach to OC. Moreover, year by year, the average age of women opting for OC has been progressively decreasing [17].

TECHNIQUES OF OOCYTE RETRIEVAL AND CRYOPRESERVATION IN ASSISTED REPRODUCTIVE TECHNOLOGY

While our study primarily focuses on the role of OC, we aim to provide a concise and accessible overview of the cryopreservation process itself, offering essential context for a better understanding of this fertility preservation technique. The initial phase of OC involves administering injectable hormonal medications to stimulate the ovaries, thereby promoting the growth and maturation of multiple ovarian follicles. The subsequent steps are illustrated in Figure 1.

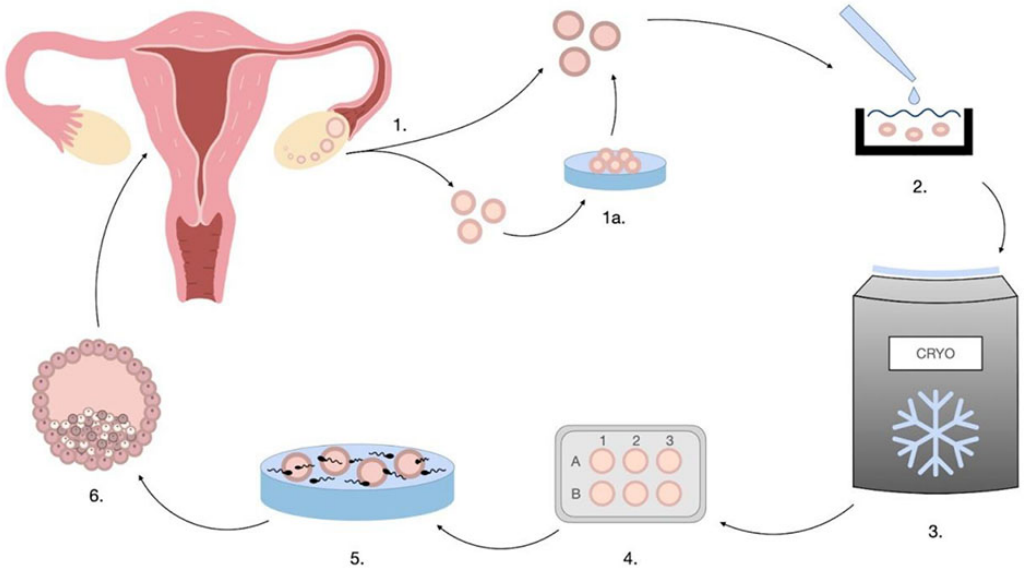

Figure 1. Puncture of the adequately developed follicles with an aspiration needle under ultrasound guidance after earlier stimulation of the ovaries with injectable hormones and selection of mature or immature oocytes. 1a. Immature oocyte in vitro maturation. 2. Mobilization of water out of the oocytes and diffusion of cryoprotectants into the oocytes to prevent formation of ice crystals. 3. Cryopreservation by rapid vitrification with the use of liquid nitrogen or by slow cooling method and storage of cryopreserved oocytes in nitrogen tanks. 4. Thawing. 5. In vitro fertilization. 6. Embryos. [18] [19]

MOTIVATIONS AND BENEFITS

Throughout history, societal norms have shaped expectations around childbearing. In many traditional cultures, early marriage and parenthood were encouraged to ensure economic security and family continuity, reinforcing the idea that motherhood was a key role for women [20]. In the second half of the 20th century, shifting gender roles and the rise of feminism challenged traditional norms. As women pursued careers and personal independence, the idea of postponing motherhood became more socially acceptable [21].

There are several underlying causes and motivations contributing to the trend of delayed motherhood, which in turn has led to a rise in the use of elective OC. Greater access to education and career opportunities has empowered women to delay motherhood. Higher educational attainment provides the skills and confidence needed to prioritize personal and professional growth before starting a family [22]. Cultural views on motherhood have shifted significantly over time. While it was once seen as a woman's primary role, modern perspectives acknowledge that women have diverse identities, goals, and aspirations beyond parenthood. This change empowers women to make more autonomous decisions about if and when to become mothers [23].

Planned OC offers women greater control over their reproductive choices by enabling them to delay motherhood without entirely sacrificing the possibility of having a genetically related child later in life. This approach supports reproductive autonomy, as it allows women to align their family planning decisions with personal, educational, or professional goals, while preserving the biological potential for future parenthood [18].

This review focuses primarily on OC in the context of delayed motherhood; however, it is important to

acknowledge the original and still most prevalent indication for this procedure—medical necessity. Medical reasons include conditions such as premature ovarian insufficiency and the gonadotoxic effects of oncological and other systemic treatments. A study conducted on a Dutch population of 1,112 patients revealed that 62.3% underwent OC due to cancer-related indications, 9.8% for non-oncological medical reasons (such as premature ovarian insufficiency, systemic disease, or other conditions), while the remaining 27.9% pursued OC for non-medical reasons [24].

Elective OC as a means of postponing motherhood not only safeguards oocytes from the detrimental effects of reproductive aging but may also offer protection against age-related diseases, such as malignancies, whose incidence increases with advancing age [25]. According to established guidelines, there is strong scientific evidence indicating that when vitrified and subsequently warmed oocytes are utilized in in vitro fertilization (IVF) or intracytoplasmic sperm injection (ICSI) procedures—particularly in younger women—their fertilization and pregnancy outcomes are comparable to those achieved using fresh oocytes. This suggests that the cryopreservation process, specifically vitrification, does not significantly compromise the developmental potential of oocytes when performed correctly. Consequently, for women of younger reproductive age, vitrified oocytes offer a reliable and effective alternative to fresh oocytes in assisted reproductive technologies, supporting their broader application in both medical and elective fertility preservation contexts [16].

COSTS AND LIMITATIONS

OC, while offering significant reproductive advantages, is not without its limitations—many of which are closely linked to the age of the patient, mirroring the natural decline in fertility observed with advancing maternal age. Just as in spontaneous conception, the concept of "optimal timing" is equally relevant in the context of elective fertility preservation. Age plays a pivotal role in determining the quality and quantity of retrieved oocytes, and consequently, the success rates of future embryo transfers [26].

As women age, particularly beyond 38 years, the biological efficiency of OC begins to decline, leading to a noticeable increase in the number of stimulation cycles required to obtain a sufficient number of mature, high-quality oocytes. This, in turn, significantly raises the financial burden associated with the procedure. The cost-effectiveness of fertility preservation diminishes as a greater number of clinical interventions—such as ovarian stimulation, oocyte retrieval, and vitrification cycles—become necessary to achieve a comparable probability of live birth seen in younger patients [27]. Therefore, while OC remains a valuable option for extending reproductive potential, its practical and economic feasibility is markedly influenced by the patient's age at the time of cryopreservation [28].

There are also several complications associated with OC stem from the process of oocyte retrieval itself. One such complication is ovarian hyperstimulation syndrome (OHSS), a condition that may arise as a result of an exaggerated response to controlled ovarian stimulation. Although often preventable with proper clinical protocols, OHSS remains a notable iatrogenic risk in the context of oocyte collection for cryopreservation. Although most cases are mild, moderate to severe forms of OHSS are reported in approximately 1% to 5% of ART cycles, making it a clinically significant concern in reproductive medicine [29]. It is also worth mentioning that despite medical advancements, advanced maternal age remains strongly associated with a heightened likelihood of obstetric complications, including increased rates of cesarean section, spontaneous preterm birth, hypertensive disorders of pregnancy such as pre-eclampsia, gestational diabetes, and intrauterine fetal demise (IUFD) [30].

EFFICACY AND OUTCOMES

Accurately estimating the effectiveness and the number of cryopreserved oocytes required to achieve successful fertilization is essential for informed decision-making regarding delayed parenthood. Moreover, assisted reproductive technologies are often financially burdensome, underscoring the need for evidence-based decision-making supported by reliable data [18].

Some studies indicate that elective OC is equally effective as using fresh donor oocytes [31] and when compared to standard IVF procedures. Furthermore, OC poses no higher risk of congenital abnormalities when compared to the general population and natural conception [32].

One study conducted in a private practice facility, involving 1283 vitrified oocytes warmed during 128 IVF cycles, demonstrated no disparity in fertilization success when compared to fresh autologous sperm injection cycles. Moreover, the use of cryopreserved oocytes increased the likelihood of successful implantation.

Despite this, the percentage of live births and continued pregnancies remained similar to IVF using fresh oocytes. Ultimately, 6.4% of oocytes that were first frozen and subsequently thawed resulted in the birth of a live child. The researchers propose freezing 15-20 oocytes for women under the age of 38 and 25-30 oocytes for women aged 38 to 40 [26].

An observational study conducted in the Netherlands evaluating the outcomes of freezing oocytes or embryos found that after 10 years, 25.5% of the oocytes or embryos were used, with a median time to return of 42 months. The live birth rate (LBR) per patient was 34.6% for cryopreserved oocytes and 33.9% for embryos,

indicating that both techniques are comparably efficient.

When data were broken down by cause of fertility preservation, the LBR was 30.2% for oncological reasons, 35.7% for benign conditions and 42.9% for elective cryopreservation [24]. An overall utilization rate of 8.4% was reported by another study group that aimed to determine the expenses and efficacy of elective OC. Women between the ages of 36 and 39 had the highest thaw rate after 10 years, at 26.6%, and the LBR was 42.3%.

Younger patients had a 10.6% chance of using oocytes, with a 63.6% LBR; older women had a 12.7% chance of unfreezing the oocytes, which led to a 17.6% success rate in obtaining a live delivery. As women aged, the cost-effectiveness of one live baby declined [33].

There were 605 cell thaws and 436 embryo transfers among 543 patients who underwent 800 oocyte freezing procedures in a different retrospective analysis carried out in a large academic reproductive center. The median number of oocytes thawed was 12, the median period between cryopreservation and unfreezing the oocytes was 4.2 years, and 61% of all patients underwent at least one transfer. The final LBR per patient was measured and found to be 39%, with effectiveness varying according to the patient's age at cryopreservation [34].

In a study carried out by the same research center, 231 participants froze a total of 3250 oocytes throughout at least one cycle of OC between 2005 and 2009. On average, ten metaphase II oocytes were frozen. 88 patients (38.1%), with an average age of 43.9, returned to use the oocytes after an average of 5.9 years. Although 37.5% of patients used donor sperm, the majority of patients created embryos with their partner. Ultimately, 27 of the 60 women who received at least one embryo transfer gave birth to 32 children [35].

In comparison to IVF without freezing at a later reproductive age, OC is more cost-effective and offers a higher chance of obtaining one or two live births when it comes to electively delaying parenting, according to one meta-analysis. The most cost-effective scenario for women desiring one live delivery was storing the oocytes at 33 years old and thawing them at 43 years old - the odds of one live birth was 73%, whereas three cycles of IVF at the age of 43 with no cryopreservation provided 50% chances [27]. Despite the fact that elective OC has revolutionized the perception of artificial reproductive techniques and is no longer referred to as an experimental procedure, more research into its efficacy is required [36]. The scarcity of research comparing pregnancy and birth problems is noticeable.

DISCUSSION

OC appears as a realistic option for individuals looking to reconcile autonomy with the biological restrictions of fertility [5]. As demonstrated in our analysis, the average age of first childbirth in many nations is already approaching or exceeding 30 years, with a significant increase in women giving birth after the age of 35 [1]. This demographic transition emphasizes the need for affordable and effective fertility preservation treatments. Importantly, OC has progressed from an experimental technique to a generally accepted and morally sound method. The vitrification procedure has greatly increased egg survival, fertilization, and LBR, making elective OC a viable and successful option for women seeking to preserve fertility [16].

Our findings also show that the success of OC is strongly age-dependent [33]. Although banked oocytes are not frequently utilized (less than 15%), having frozen oocytes can provide women with psychological security. This demonstrates a subjective benefit of OC that extends beyond LBR and should be evaluated during patient counseling.

Although elective OC has become an established fertility preservation technique, several limitations remain. Utilization rates of stored oocytes are low, and success is not guaranteed even in optimal conditions. Many patients require multiple stimulation cycles, which increases both financial costs and physical burden [27].

Furthermore, most available data are derived from retrospective studies, and long-term outcomes related to offspring health remain underreported. Future research should prioritize prospective studies, explore cost-effectiveness in varied healthcare contexts, and develop strategies to improve awareness and access to OC.

CONCLUSION

In conclusion, OC is a reliable fertility preservation method with the highest efficacy when performed prior to the age of 35. While it expands reproductive choices for women, particularly in the context of delayed parenthood, its success is contingent on timely intervention and appropriate patient selection. Future strategies should focus on accessibility, awareness, and integration of OC into standard reproductive counseling.

IMPLICATIONS FOR PRACTICE

Clinicians should consistently inform women, especially those under 35, about the age-dependent success of elective OC as part of reproductive counseling. When performed early, OC yields live birth rates similar to those achieved with fresh IVF cycles and offers greater cost-efficiency. Given the rapid decline in fertility after age 38, timely referral to fertility specialists is crucial. Patients must be counseled that OC increases the chance of future

conception but it does not ensure success. Integrating OC discussions into routine gynecological care may support informed decision-making and empower women in their reproductive planning.

AUTHORS CONTRIBUTIONS

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Writing - original draft preparation: Szymon Korczyk; Aleksandra Kaczmarek; Małgorzata Fudali; Magdalena Dorobek; Ewa Otręba, Mikołaj Szewczykowski; Tomasz Klinkosz

All authors approved the final version of the manuscript.

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