

Predictors of Embryo Implantation Success among Women Undergoing In-Vitro Fertilization in Benin City Nigeria

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Abstract:

Background: The effectiveness of in-vitro fertilization (IVF) depends on a number of interrelated maternal, embryonic, uterine, therapeutic, and health-system aspects. However, embryo implantation is a crucial stage of IVF. Predictors of successful embryo implantation in women having IVF in Benin City, Nigeria, were investigated in this research. **Methods:** Relevant evidence on patient characteristics, causes of infertility, ovarian-reserve markers, treatment variables, embryo quality, endometrial and uterine factors, laboratory practices, and sociodemographic barriers was reviewed and synthesized. **Results:** IVF prognosis was correlated with maternal age, ovarian reserve status, embryo quality, endometrial thickness, uterine features, and the technical complexity of embryo transfer. While AMH and antral follicle count were more helpful in predicting ovarian response than direct implantation, embryo quality and endometrial state seemed to be more informative than the quantity of embryos transplanted alone. Treatment options were also impacted by male-factor infertility and restricted access to reasonably priced therapies. **Conclusion:** Implantation success is multifactorial; individualized care, standardized IVF practice, improved affordability and locally generated prospective research are recommended.

Keywords: embryo implantation, IVF, endometrial thickness, embryo quality, AMH, Benin City, Nigeria

1. Introduction

In low- and middle-income countries (LMICs), where cultural and social expectations frequently link reproductive success to individual identity, marital stability, and family fulfillment, infertility is a significant reproductive health and public health problem (Inhorn & Patrizio, 2015). It is predicted that 186 million people and 48 million couples

worldwide suffer from infertility (WHO, 2020). The burden is particularly high in sub-Saharan Africa, where sexually transmitted illnesses and genital tract infections significantly increase infertility in both men and women (Ombelet *et al.*, 2020). Low sperm concentration, poor motility, and aberrant sperm morphology are frequently linked to infertility in males (WHO, 2020). Ovulatory problems, tubal blockage, uterine abnormalities, endometriosis, and endocrine dysfunction are significant causes in women (Koster-Oyekan, 1999; Ekwuazi *et al.*, 2022). In Nigeria, the impact of infertility extends beyond its biological consequences. Limited documentation, inadequate public-health infrastructure, restricted access to specialist services, and dependence on expensive private facilities continue to constrain infertility care (Owolabi *et al.*, 2021). High treatment costs, limited insurance coverage, variation in clinical success rates, and weak health-information systems further restrict access to assisted reproductive technology (ART) (Okafor *et al.*, 2023). Because many fertility services are delivered in private clinics without standardized documentation or long-term follow-up, national and regional assessment of treatment trends and outcomes remains difficult. Treatment failure may also expose couples to considerable emotional, social, and financial distress, potentially reducing confidence in ART services.

For couples who are unable to conceive through traditional therapy or for whom alternative therapies are unlikely to be successful, in-vitro fertilization (IVF) is a crucial part of ART. In IVF, oocytes are extracted, fertilized with sperm outside of the human body, the resultant embryos are cultured in a lab, and one or more embryos are transferred into the uterus (Murtaza *et al.*, 2019). In many regions of the world, including Africa, IVF has been a recognized therapeutic option since the birth of Louise Brown, the first child born by the process, in 1978. Tubal-factor infertility, endometriosis, ovulatory dysfunction, advanced maternal age, infertility that cannot be explained, and severe male-factor infertility can all be treated with IVF.

Advances in laboratory techniques, including the use of intracytoplasmic sperm injection when appropriate, have expanded its potential application in cases involving markedly impaired sperm count, motility, or morphology (Bungum *et al.*, 2021). In Nigeria, however, the clinical benefits of IVF must be considered alongside substantial barriers to access, including treatment expense, uneven availability of specialist services, differences in laboratory capacity, and inconsistent outcome reporting. These challenges make locally generated evidence on patient characteristics, treatment patterns, and clinical outcomes essential for improving care.

The process by which a growing embryo adheres to and establishes itself inside the receptive endometrium is known as embryo implantation. Therefore, the percentage of

transplanted embryos that implant in the uterus is typically used to measure implantation success.

It is a clinically important intermediate outcome because it reflects the interaction among embryo competence, endometrial receptivity, embryo-transfer technique, maternal age, uterine factors, and other patient- and treatment-related characteristics. Implantation is also an important measure of IVF laboratory and clinical performance. A higher implantation rate may indicate that transferred embryos and the uterine environment are favorable for early developmental progression. However, implantation does not by itself demonstrate a viable pregnancy or a successful treatment outcome. An embryo may implant but subsequently fail to develop, and implantation rates can be influenced by the number of embryos transferred and by how implantation is defined and measured. For this reason, implantation success should be interpreted alongside later pregnancy and birth outcomes rather than used as a substitute for them.

2 Context of IVF in Benin City and Nigeria

According to population-based research, 10–15% of people have infertility, which is a serious reproductive health issue. Among couples who require specialist infertility care, a substantial proportion may eventually need assisted reproductive technology (ART), particularly when conventional medical or surgical treatments have failed (Rodriguez-Armas and Daya, 1998; Bhattacharya *et al.*, 2007). In Nigeria, infertility is further compounded by conditions such as obstetric complications, untreated or inadequately treated sexually transmitted infections, and other causes affecting both women and men (Orhue and Aziken, 2008; Okonofua, 2003). Because some cases do not respond to conventional treatment, ART remains an important component of comprehensive infertility care (Orhue and Aziken, 2008). Despite this need, access to ART services in Nigeria has historically been limited. The National Hospital in Abuja and the University of Benin Teaching Hospital (UBTH) in Benin City were the two government-owned facilities that housed less than two of the nation's more than fourteen IVF-ET centers (Aziken *et al.*, 2010). IVF services in private facilities were generally considered expensive, whereas public-sector centres were established partly to provide more affordable treatment to couples seeking assisted conception. The Human Reproduction Research Programme (HRRP) at UBTH therefore occupies an important position within Nigeria's public reproductive-health system. Its ART programme had already been established before the study conducted between June 2007 and May 2008, providing a setting in which patients' knowledge, perceptions and willingness to accept IVF could be examined (Aziken *et al.*, 2010).

The use of ART is influenced by patients' opinions about IVF and their knowledge of infertility in addition to the availability of treatments. Although only 59.6% of participants

in the Benin City research accurately comprehended the fundamental processes involved, 74.2% of respondents had heard of IVF-ET. Nevertheless, attitudes towards IVF were generally favourable: 71.9% considered children conceived through IVF acceptable, and 70.1% regarded them as normal (Aziken *et al.*, 2010). These reviews suggest that awareness of IVF was relatively high among women attending an infertility clinic, but that important gaps remained in their knowledge of infertility causes and the technical processes involved in IVF treatment. The patients attending the HRRP at UBTH were predominantly women in their later reproductive years. Of the 178 respondents, 71.9% were aged 30–39 years, while 14.7% were aged 40 years or older; 61.8% had never previously delivered a child (Aziken *et al.*, 2010). The duration of infertility was also substantial: 27.0% had experienced infertility for at least ten years, and 43.8% reported infertility lasting between five and nine years (Aziken *et al.*, 2010). The relatively advanced age of the patients as well as the prolonged duration of infertility may indicate delayed presentation for specialist care. Such delays may reflect financial constraints, limited awareness of available services, reliance on alternative treatments, or the social and emotional pressures associated with childlessness.

The reviews also highlight the gendered nature of infertility care. Although 87.6% of respondents acknowledged that male factors could contribute to infertility, only 39.7% were able to identify specific male causes. By comparison, 62.5% correctly identified female causes of infertility (Aziken *et al.*, 2010). Aziken *et al.*, (2010) recommended that limited recognition of male infertility may contribute to women presenting to infertility clinics without their partners, thereby reinforcing the perception that infertility is primarily a woman's problem. This pattern has important implications for ART, since effective infertility evaluation and treatment require the assessment and, where necessary, treatment of both partners. Financial barriers were a major determinant of access to IVF. Although most respondents expressed some willingness to undergo treatment, approximately 71.2% perceived IVF as prohibitively expensive or accessible only to wealthy individuals. In addition, 24% stated that they would not accept IVF because of cost, stigma or religious concerns. The previous findings underscore the importance of government-supported IVF services and the expansion of affordable ART programmes within tertiary healthcare institutions. In this regard, the public IVF programme at UBTH provides an important avenue for couples who might otherwise be unable to afford treatment in private facilities (Aziken *et al.*, 2010).

The uptake of IVF in Benin City is shaped by the interaction of demographic, socioeconomic, cultural and health-system factors. Higher levels of education were linked to more positive views regarding IVF and greater understanding of infertility. Respondents with postsecondary education were more inclined to view IVF-conceived children as normal and acceptable, and they were also much more educated about both male and female causes of infertility. Acceptance of IVF also increased with educational level, consistent with evidence that education influences health literacy, health-seeking behaviour

and the use of specialized medical services (Chukwudebelu, 2003; Harrison, 1989). Socioeconomic circumstances similarly influence access to treatment. A large proportion of respondents viewed IVF as expensive, reflecting the broader difficulty of delivering advanced reproductive technologies in settings with constrained health-system resources and high levels of poverty (Ajayi, Ed; Okonofua, 1996). The cost of treatment therefore remains a central obstacle to the wider use of IVF in Nigeria. The authors responded by advocating for more government participation in the delivery of reasonably priced ART therapies and the growth of public-sector fertility initiatives.

Cultural, religious as well as social beliefs also affect the acceptability of IVF. Although most respondents considered IVF-conceived children to be normal and acceptable, 28.1% did not regard them as acceptable. The reasons cited included the belief that IVF was not a natural process (28.1%), religious concerns (20%), and stigma (20%) (Aziken *et al.*, 2010). More broadly, ethical and moral questions related to ART, including gamete donation, embryo donation, embryo cryopreservation, the disposition of surplus embryos and sex selection, may shape public attitudes and influence decisions about treatment (John, 2000; Aniebue and Aniebue, 2008; Papageorgiou, 2006; McMahon *et al.*, 2000; Laruelle and Englert, 1995). These concerns are likely to be particularly important in settings where reproductive decisions are closely linked to religious values, family expectations and community perceptions. The health-system context is therefore central to understanding IVF utilization in Benin City. Limited public-sector capacity, the high cost of private treatment, minimal government involvement, gaps in patient knowledge, and cultural and religious concerns collectively influence access to and acceptance of ART. The experience of UBTH illustrates the potential contribution of public-sector fertility services to improving access to IVF in Nigeria. At the same time, it demonstrates that expanding ART requires more than establishing treatment centres. Sustainable improvement will also depend on public education, earlier referral, the involvement of both partners in infertility evaluation, affordable treatment, and stronger integration of infertility care into the wider Nigerian healthcare system (Orhue and Aziken, 2008, Ajayi, Ed). The aim is to systematically review the predictors of embryo implantation success among women undergoing IVF in Benin City, Nigeria.

3 Predictors of implantation success

3.1 Patient-related predictors

Maternal age

Given that aging is linked to decreased fertility and altered ovarian reserve, maternal age is a crucial patient-related factor in assisted reproductive technology (ART). The mean age of the women having IVF or ICSI in the Ottun *et al.* trial was 37.7 ± 6.2 years, and almost two-thirds of them were 35 years of age or older. The scientists found that one significant risk

linked to decreased ovarian reserve was getting older, especially beyond the age of 35 (Orhue et al., 2012).

The hormonal results also showed this link. Maternal age exhibited a weak negative association with anti-Müllerian hormone (AMH) ($r = -0.479$, $p < 0.001$) and a faint positive correlation with serum follicle-stimulating hormone (FSH) ($r = 0.306$, $p < 0.001$). Practically speaking, greater FSH and lower AMH concentrations were linked to older age (Bozkurt et al., 2016). There have also been reports of diminished ovarian reserve beyond around age 37 (Faddy et al., 1992). Therefore, while advising patients about their anticipated reaction to ovarian stimulation and the possibility of a successful IVF/ICSI outcome, maternal age should be taken into account.

Body mass index

Another patient trait that can be important for ART results is body mass index (BMI). The BMI of the Nigerian cohort was 27.3 ± 4.9 kg/m², with a median of 27.0 kg/m² (interquartile range (IQR) 24.1–30.5 kg/m²) (Table 2). Serum FSH and BMI had a slight but statistically significant positive connection ($r = 0.173$, $p = 0.011$). BMI did not, however, significantly correlate with either post-ovulation endometrial thickness ($r = 0.072$, $p = 0.263$) or AMH ($r = -0.139$, $p = 0.148$). These findings indicate that BMI had, at most, a limited relationship with the ovarian-reserve and endometrial parameters measured in this population. Although BMI remains clinically relevant when evaluating patients undergoing ART, the study did not demonstrate that it independently predicted implantation or clinical pregnancy (Bozkurt et al., 2016).

Ovarian-reserve markers

Serum FSH and AMH are frequently used to measure ovarian reserve and can be used to describe the reproductive status of women receiving antiretroviral therapy. The median blood FSH and AMH concentrations in the study population were 8.1 IU/L and 6.3 pmol/L, respectively. Maternal age was linked to both markers: AMH declined with age, whereas FSH rose. In particular, there was a mild negative connection ($r = -0.479$, $p < 0.001$) and a faint positive correlation ($r = 0.306$, $p < 0.001$) between age and AMH. Ottun et al. reported that this pattern was reliable with the discoveries of Bozkurt et al., (2016) who also described an age-related increase in basal FSH and an inverse relationship between age and AMH. The authors further cited evidence that diminished ovarian reserve becomes more apparent after 37 years of age. FSH and AMH may therefore be useful when assessing ovarian reserve and counselling women before IVF. Nevertheless, the present study primarily demonstrated their association with age and ovarian-reserve status; it did not establish either marker as an independent predictor of embryo implantation (Faddy et al., 1992; Bozkurt et al., 2016). Previous reproductive history may also be relevant when evaluating patients for ART. In the Nigerian study, 89.7% of women had never delivered, and 91.6% had no living child at presentation. The authors observed that women proceeding to ART after unsuccessful

conventional infertility treatment were predominantly those without a previous delivery or living child. This finding was comparable with that of Orhue *et al.*, (2012) who reported that 82.4% of women in their Nigerian IVF study were nulliparous. Most women in the cohort were also undergoing ART for the first time. Oocyte retrieval was performed during the first treatment cycle in 94.0% of participants, during a second cycle in 5.0%, and during three or more cycles in 1.0%. These numbers demonstrate that women experiencing their first documented ART cycle made up the majority of the cohort. However, Ottun *et al.* (2012) did not report a direct statistical association between the number of previous IVF cycles and clinical pregnancy or implantation. Previous IVF treatment should therefore be regarded as an important aspect of treatment history, but the available data are insufficient to conclude that the number of previous cycles independently predicts implantation success.

3.2 Infertility-related predictors

Cause of infertility

Understanding differences in infertility patterns and treatment requirements across populations requires an understanding of the cause of infertility. Because different studies have different definitions of infertility, diagnostic criteria, study methodologies, and source populations, it is difficult to compare them. Therefore, both population-based and institution-based studies that detailed the main causes of infertility and provided the percentages of primary and secondary infertility were included in the meta-analysis by Abebe *et al.* (2020). Across the included studies, female-related factors accounted for approximately 54% of infertility cases (Abebe *et al.*, 2020). This estimate is broadly consistent with the findings of previous meta-analyses, which attributed about half of infertility cases to female-related causes (Agarwal *et al.*, 2015; Eldib *et al.*, 2018). Pelvic inflammatory illness, tubal factors, prior abortion, and ovulatory dysfunction were the most commonly reported female reasons (Direkvand-Moghadam *et al.*, 2013). Previous research highlights the significance of avoiding and treating reproductive tract infections and problems associated with abortion, both of which may significantly increase infertility (Obuna *et al.*, 2012; Ekwere *et al.*, 2007). Although female-related causes represented the largest proportion, infertility should not be regarded as predominantly a female condition. Approximately 22% of infertility causes in the meta-analysis were attributed to male factors (Abebe *et al.*, 2020).

Duration of infertility

The period of infertility is clinically relevant because prolonged attempts to conceive may be associated with delayed presentation, increasing age at treatment and a greater likelihood of requiring specialist intervention. This limitation also illustrates one of the difficulties involved in synthesizing infertility research. Studies conducted in different settings may use different definitions, diagnostic criteria and reporting practices, making it difficult to

compare duration-related findings directly. Future studies should report infertility duration using clearly defined categories and should examine its relationship with age, underlying cause, primary or secondary infertility, and treatment outcomes.

Primary versus secondary infertility

The proportional percentages of primary and secondary infertility varied significantly across the studied studies. According to the meta-analysis, this variation was closely related to the distribution of underlying causes in the study populations. Secondary infertility was more common in areas where sexually transmitted infections, post-abortion infection and infection-related complications after a first pregnancy were prevalent (Panti *et al.*, 2014; Kitilla, 2001; Hailemariam, 1999). By contrast, primary infertility predominated in settings where these conditions were more effectively prevented or managed (Benbella *et al.*, 2018; Benksim *et al.*, 2018; Mokhtar *et al.*, 2006). The overall pooled percentage of primary and secondary infertility across Africa were generally comparable, despite differences across specific research. This tendency is not consistent with the results of a meta-analysis conducted in Iran, where 78.4% of cases had primary infertility (Abebe *et al.*, 2020). The discrepancy can be due to variations in the incidence of pelvic inflammatory disease, puerperal sepsis, abortion-related complications, and STDs. These diseases continue to be significant causes of secondary infertility in many developing-country contexts (Chigumadzi *et al.*, 1998; Panti and Sununu, 2014; Obuna *et al.*, 2012; Ekwere *et al.*, 2007). Additionally, regional variations were noted. While secondary infertility was most common in East Africa (69.63%), primary infertility was more common in North Africa (70.56% of patients) (Abebe *et al.*, 2020). The World Health Organization statistics that indicate a higher burden of secondary infertility in sub-Saharan Africa are consistent with the higher percentage of secondary infertility in East Africa (Cates *et al.*, 1985). Sexually transmitted diseases, prior abortions, labor problems, poor access to healthcare, improper use of antibiotics, and antimicrobial resistance have all been found to be significant risk factors in East African studies (Larsen *et al.*, 2006; Ikechebelu *et al.*, 2003). The stated distribution of infertility also seems to be influenced by the timing of the research. While more recent studies indicated a larger proportion of primary infertility, older studies often revealed a higher pooled proportion of secondary infertility. One possible explanation is that older studies were conducted during periods of poorer healthcare coverage and a higher prevalence of untreated or inadequately treated infections, circumstances that would be expected to increase secondary infertility (Gerais *et al.*, 1992). Because these comparisons may also reflect differences in study populations and diagnostic methods, the temporal pattern should be interpreted cautiously.

Male-factor infertility and sperm parameters

About 22% of the reasons listed in the meta-analysis were male-factor infertility (Abebe *et al.*, 2020). The most frequently described male-factor conditions were oligospermia and

asthenozoospermia, both of which relate to reduced sperm concentration or impaired sperm motility. The previous studies indicate that abnormalities in sperm quality constitute an important component of infertility and should be actively investigated during the initial assessment of couples. The emphasis on male-factor infertility also supports the need for routine semen analysis and appropriate assessment of sperm concentration, motility and other relevant parameters. Treatment strategies aimed at improving sperm quality may be beneficial in selected patients. For instance, a meta-analysis of randomized controlled trials found that supplementing with selenium and coenzyme Q₁₀ improved sperm-quality metrics (Buhling *et al.*, 2019). However, the therapeutic significance of such therapies relies on whether increases in sperm quality result in significant reproductive outcomes; hence, improvements in semen characteristics should not be immediately construed as evidence of enhanced live-birth or pregnancy rates.

3.3 Predictors associated with treatment

Ovarian stimulation protocol

Although ovarian response and ovarian reserve were central to several predictive models, most available synthesis does not identify a particular stimulation regimen as consistently superior (Salih *et al.*, 2026). This distinction is important because markers such as AMH as well as antral follicle count (AFC) primarily reflect the expected ovarian response, rather than the independent effect of the stimulation protocol itself. Zeng *et al.* (2025) showed that AMH was more useful for predicting oocyte yield in women with diminished ovarian reserve (DOR), whereas AFC more accurately predicted the availability of viable day-3 embryos. Previous researches support the use of ovarian-reserve markers to individualize treatment planning, but they do not establish a specific stimulation protocol as a predictor of clinical pregnancy otherwise live birth. The reviewed evidence also suggests that the relationship between treatment response and outcome may be non-linear. Xia *et al.* (2024) used restricted cubic splines to model the effects of age and oocyte number, illustrating the value of methods that can capture relationships not adequately represented by a simple linear assumption. Consequently, the choice of stimulation protocol should be interpreted as a treatment-planning factor whose effectiveness may depend on age, ovarian reserve and the patient's underlying clinical characteristics.

Number of oocytes retrieved

Because it indicates the ovarian response and establishes the quantity of embryos that may be transferred or cryopreserved, the number of oocytes recovered is a crucial intermediate treatment result. In the reviewed literature, oocyte number was included among the variables associated with IVF success (Salih *et al.*, 2026), and Xia *et al.* (2024) specifically modelled its relationship with outcome alongside maternal age. The predictive value of oocyte number should nevertheless be interpreted carefully. A greater number of retrieved

oocytes may increase the opportunity to obtain viable embryos, but oocyte quantity does not necessarily reflect oocyte competence or guarantee implantation. The results of Zeng *et al.* (2025), who found that AMH was especially helpful for predicting oocyte yield while AFC was more informative for predicting the availability of viable day-3 embryos in women with DOR, confirm this difference. Therefore, it seems that the quantity of oocytes serves primarily as a measure of therapy response and potential for embryo formation. The parameters of the transfer cycle, chromosomal competence, and embryo quality are likely to modulate its effect on ultimate results.

Fertilization method

This limitation is relevant because the indication for ICSI may itself be associated with poorer semen quality or previous fertilization problems. Consequently, a direct comparison between IVF and ICSI would require careful adjustment for the underlying indication, maternal age, ovarian reserve, sperm characteristics and embryo-related factors. The reviewed evidence therefore supports a couple-focused assessment of treatment prognosis, particularly through the inclusion of male parameters such as total progressive motile count (TPMC) as well as sperm DNA fragmentation index (DFI), but it does not demonstrate that one fertilization method consistently produces superior pregnancy outcomes (Wang *et al.*, 2025; Bereczki *et al.*, 2025).

Number of embryos transferred

Because it directly affects both the chance of implantation and the likelihood of multiple pregnancies, the number of embryos transferred is a potentially significant treatment-related predictor. The data emphasizes the quality of embryos more than their quantity. The quantity of high-quality or top-quality embryos was found to be a significant predictor of clinical pregnancy and cumulative live birth by Zeng *et al.* (2025) and Zhu *et al.* (2025). In younger women, Zeng *et al.* (2025) reported that day-3 embryo quality could be more predictive of clinical pregnancy than maternal age. These findings suggest that the developmental competence of the embryos transferred may be more informative than the transfer number alone. Therefore, embryo number should not be interpreted independently of embryo quality, maternal age, embryo stage and the clinical strategy used for transfer.

Overall, the available evidence suggests that treatment-related prognosis is shaped by a sequence of linked events: The amount of ovarian response is determined by ovarian stimulation; the pool of embryos that can be produced is influenced by the number of oocytes recovered; fertilization and laboratory procedures have an impact on embryo development; and transfer decisions determine which embryos are eventually placed in the uterine environment. Among these stages, the reviewed studies provide the strongest evidence for the prognostic importance of oocyte number and embryo quality, particularly when interpreted alongside maternal age and ovarian-reserve markers (Zhu *et al.*, 2025; Zeng *et al.*, 2025; Xia *et al.*, 2025). Regarding the independent impacts of stimulation

regimen, fertilization method, fresh vs frozen transfer, number of embryos transferred, or transfer technique and time, there is still not enough data to make strong judgments. Because some of the prediction models were created retrospectively in single-center populations, there are issues with selection bias and generalizability that call for careful interpretation (Bai *et al.*, 2025; , Liu *et al.*, 2024; Yang *et al.*, 2022).

3.4 Endometrial and uterine predictors

In oocyte-donation cycles, recipient-related uterine factors are important because the donated oocyte largely reduces the influence of recipient ovarian age and ovarian reserve. The principal uterine contributors to pregnancy include the endometrium, myometrium and cervix (Abdalla *et al.*, 1994; Noyes *et al.*, 2001; , Bustillo *et al.*, 1995).

Recipient age and uterine ageing

Advanced recipient age has been associated with poorer outcomes in some oocyte-donation studies, particularly from approximately 45 years onwards (Baird *et al.*, 2005; Borini *et al.*, 2011). Most pregnancies occurred among recipients aged 45–49 years, and neither miscarriage nor live-birth rates appeared to vary significantly with age. One recipient aged 52 years also achieved pregnancy and live birth, although this individual outcome was not statistically informative. In conventional IVF, the effect of age is strongly related to declining ovarian function and the resulting reduction in oocyte quality and embryo competence (Meldrum, 1993; Navot *et al.*, 1994). In donor-oocyte cycles, the use of oocytes from young, healthy donors limits the contribution of recipient ovarian ageing and allows the uterine component of reproductive ageing to be examined more directly. This supports the view that uterine ageing may occur more slowly than ovarian ageing (Check *et al.*, 2010). The study population, however, consisted mainly of women aged 40–50 years, while only three recipients (1.9%) were younger than 35 years; most of the younger recipients had premature ovarian failure or resistant ovaries. This age distribution limits the ability to compare outcomes across the full reproductive age range (Osaikhuwuomwan *et al.*, 2021). According to other researchers, women over 40 may have decreased uterine receptivity and, to some extent, embryo viability (Abdalla *et al.*, 1997). Consequently, the lack of an age-related difference in this study should not be taken as evidence that receiver age has no bearing on the result. Instead, it could be due to the small sample size, the use of donor oocytes, and the very small proportion of younger recipients.

Endometrial thickness

In order to determine if the endometrium is ready for embryo implantation, endometrial thickness is frequently measured during the late follicular phase. In IVF and embryo-recipient cycles, a thicker endometrium has often been linked to a higher chance of pregnancy (Noyes *et al.*, 1995). According to some research, a threshold beyond which conception becomes less likely is an endometrial thickness of less than about 9 mm (Noyes

et al., 2001). The previous studies support the prognostic value of endometrial thickness. The pregnant group had a thicker endometrium than the non-pregnant group, and pregnancy was significantly more frequent when endometrial thickness was at least 8 mm. An endometrium measuring less than 7 mm was related with a relatively lesser likelihood of pregnancy (Osaikhuwuomwan *et al.*, 2021).. These findings suggest that endometrial thickness may provide useful information about implantation potential in donor-oocyte cycles, although it should be treated as a probabilistic marker rather than an absolute requirement for treatment. This caution is warranted because pregnancies and live births have been reported with endometrial thickness of 6 mm or less (Mirkin *et al.*, 2003). Accordingly, the identification of a thin endometrium does not necessarily justify cancelling a cycle or cryopreserving the embryos. If implantation does not occur, however, further assessment may be appropriate before a subsequent transfer. This evaluation should include consideration of intrauterine pathology, particularly intrauterine adhesions, when clinically indicated.

Endometrial pattern

Endometrial pattern has also been described as a potentially useful predictor of pregnancy in IVF cycles (Noyes *et al.*, 1995). Nevertheless, the current study did not evaluate endometrial pattern. Therefore, the predictive significance of its existence in this group cannot be inferred. Future studies should record endometrial pattern alongside thickness and, where possible, use standardized ultrasound criteria to improve comparability between studies.

Uterine fibroids and other uterine structural factors

Fibroids have been found to have varying impacts on implantation and pregnancy rates following IVF (Bustillo et al., 1995; Surrey and Lietz, 2001). Therefore, in actual practice, the size, quantity, and anatomical connection of fibroids to the uterine cavity may influence the choice to proceed with embryo transfer. Many patients chose to have at least one embryo transfer without first undergoing surgery, according to Zenke and colleagues (Zenke et al., 2004), with the knowledge that myomectomy would be considered if implantation failed or the pregnancy terminated in miscarriage. This strategy could be useful in environments where uterine fibroids are prevalent, but choices should be tailored to the patient's reproductive history and the fibroid's features.

Cervical and embryo-transfer-related uterine factors

Embryo transfer is a technically important stage of ART, despite its apparent simplicity, and remains one of the least predictable steps in the treatment process (Embryo transfer- the elusive step. In stud J(ed), 2003). Difficult transfers were more common in the non-pregnant group and were associated with a less favourable IVF outcome. Previous reports identifying difficult embryo transfer as a significant contributor to implantation failure in IVF and donor-oocyte cycles (Tomas *et al.*, 2002; Noyes *et al.*, 1999). A preliminary trial transfer using

a rigid catheter during the initial evaluation may help identify cervical stenosis, tortuosity or other technical difficulties. When passage is difficult, cervical dilatation or hysteroscopic assessment may be considered before the definitive transfer, depending on the clinical findings (Osaikhuwuomwan *et al.*, 2021). Although some studies have reported better outcomes with alternative transfer routes, such as ZIFT or GIFT, compared with transcervical embryo transfer (Safdarian and Peyvandi, 2005), the present study evaluated transcervical transfer exclusively and therefore cannot compare different transfer routes. The outcome may also be influenced by procedural details that were not evaluated in the study. Cervical mucus clearance, cervical flushing, catheter type, reflux, the location of embryo deposition, the orientation and properties of the microdroplet carrying the embryos, and the use of a previous dummy transfer are some of these. Future prospective studies should take these parameters into account since they have the potential to impact the technical quality of embryo implantation.

3.5 Laboratory and clinic-related predictors

The quality of the laboratory and the clinical procedures used at a fertility center can also affect implantation results, therefore the success of assisted reproductive technology (ART) is not only dependent on the patient or the embryo. According to the ESHRE guidelines, significant external factors that might influence variations in implantation success include laboratory performance, embryo evaluation, embryo-transfer methods, clinic competence, and the application of standardized protocols. But rather than being direct causes of recurrent implantation failure (RIF), these characteristics should be seen as contextual indicators. The quality and evaluation of embryos is one of the most crucial aspects of laboratory work. Even when chromosomally euploid, embryos with poor morphological quality or aberrant developmental patterns often have reduced reproductive potential (Shear *et al.*, 2020; Zhan *et al.*, 2020; Bamford *et al.*, 2022). Embryo grading is not entirely objective, though. Research has revealed significant variations in embryo grading between IVF facilities, which may have an impact on the choice of embryos and, eventually, the results of therapy (Khosravi *et al.*, 2019; Cimadomo *et al.*, 2022; Fordham *et al.*, 2022). Although their clinical use is still being studied, new technologies like artificial intelligence and time-lapse imaging may increase the consistency of embryo evaluation (Kragh & Karstoft, 2021; Riegler *et al.*, 2021). Additional laboratory indicators have also been studied as potential implantation predictors. For instance, it has been suggested that the amount of mitochondrial DNA (mtDNA) indicates the viability of the embryo. Studies have reported positive, negative, or no correlation between mtDNA levels and implantation or pregnancy outcomes, but the results are still mixed (Tan *et al.*, 2014; Diez-Juan *et al.*, 2015; Fragouli *et al.*, 2017; Ravichandran *et al.*, 2017; Treff *et al.*, 2017; Victor *et al.*, 2017).

Clinic-related factors are equally important because differences in expertise, laboratory standards, embryo-transfer policies, and clinical decision-making may contribute to

variation in outcomes between centres. According to the ESHRE standards, ART treatments should be carried out by individuals who are suitably certified and trained, utilizing cutting-edge technology and standard operating procedures. Consistency in clinical and laboratory practice is particularly important because variations in embryo assessment and transfer strategies can make it difficult to compare treatment outcomes across fertility centres (ESHRE Working Group on Recurrent Implantation Failure, *et al.* 2023). Finally, prediction models may help clinicians understand how laboratory and clinical factors interact with patient and embryo characteristics. Important variables include maternal age, embryo euploidy where genetic testing is performed, and the number as well as developmental phase of embryos transferred. Existing prediction models incorporate factors which include age, body mass index, infertility period as well as cause, previous pregnancy or IVF history, ovarian reserve, and treatment characteristics. Nevertheless, no single model currently captures all the factors that determine implantation success. Overall, laboratory and clinic-related predictors provide an important part of the explanation for variation in ART outcomes. Rather than considering RIF as the result of one isolated problem, it is more appropriate to view implantation as the outcome of several interacting factors involving the patient, embryo, laboratory, and clinical environment. This supports an individualized approach in which the quality and consistency of laboratory and clinical practices are considered alongside patient- and embryo-related characteristics when evaluating recurrent implantation failure (ESHRE Working Group on Recurrent Implantation Failure, *et al.* 2023).

3.6 Sociodemographic and access-related predictors

Sociodemographic circumstances and access to fertility services influence who can obtain in vitro fertilization (IVF), when treatment is initiated, and whether patients are able to complete or repeat treatment. These factors are especially important in Nigeria, where infertility may be accompanied by substantial social pressure, while IVF services remain costly and are concentrated mainly in urban centres. Consequently, access to assisted reproductive technology (ART) is determined not only by clinical need, but also by household resources, place of residence, educational opportunities, cultural beliefs and the availability of specialized reproductive-health facilities (Chiware *et al.*, 2021; Lawrence *et al.*, 2021).

Economic status

Financial capacity is one of the strongest access-related determinants of IVF utilization. The cost of fertility medications, consultations, laboratory procedures and embryo-transfer cycles places treatment beyond the reach of many Nigerian couples. The financial burden becomes even greater when treatment is unsuccessful and additional cycles are required, potentially preventing couples from continuing care or returning for further treatment (Chiware *et al.*, 2021; Gardner *et al.*, 2023). Limited protection coverage and inadequate

public-sector funding further widen this gap. Couples with greater financial resources are therefore more likely to reach specialized fertility centres, afford the initial treatment cycle and sustain care when repeated attempts are necessary.

Geographical location and healthcare infrastructure

Place of residence also affects the opportunity to access IVF. Fertility clinics and specialized reproductive-health services are concentrated primarily in urban areas, leaving couples in rural and underserved communities with fewer treatment options. Long travel distances, transportation costs, limited healthcare infrastructure and shortages of trained reproductive-health professionals may increase both the financial as well as emotional burden of treatment (Adeleye *et al.*, 2023). As a result, couples with similar medical indications may face very different prospects of receiving IVF depending on where they live. Geographical barriers may also affect continuity of care. IVF requires repeated consultations, monitoring visits, laboratory procedures and follow-up appointments, making treatment particularly difficult for patients who must travel long distances. These demands can lead to delayed presentation, missed appointments or discontinuation of treatment, even when patients are medically eligible and motivated to proceed.

Education and awareness

Education and access to reliable reproductive-health information can influence how infertility is understood and when professional care is sought. Limited awareness may encourage misconceptions about the causes of infertility, promote reliance on ineffective treatments or delay referral to specialist services. By contrast, better health literacy may help couples recognize infertility as a medical condition and seek appropriate evaluation earlier (Lawrence *et al.*, 2021; Dimitrov *et al.*, 2022). Education may therefore affect both the initial decision to pursue ART and the ability to understand the procedures, costs and expectations associated with IVF. Cultural and social expectations surrounding parenthood also shape attitudes towards fertility treatment. In settings where having children is closely linked to personal identity, marriage and family fulfilment, infertility may expose couples, particularly women, to blame, stigma and psychological distress (Vasudevan & Bhuvaneswari, 2023). Fear of criticism or social judgment may discourage couples from discussing infertility, seeking specialist care or disclosing their use of ART. Religious and cultural beliefs may also influence whether IVF is considered acceptable, especially when treatment involves donor gametes, embryo cryopreservation or other procedures that raise ethical concerns. These pressures can affect men and women differently. Women may bear a disproportionate share of social blame and may be more likely to undergo repeated investigations or treatment, even when infertility involves a male factor. Such gendered expectations may delay comprehensive evaluation of both partners and may increase the emotional burden associated with infertility care.

Ethnicity, social background and discrimination

Ethnicity, social background and experiences of discrimination may create additional barriers to fertility care. Qualitative research has identified problems related to communication, cultural expectations, trust in healthcare providers and the organization of fertility services among minority groups (Kirubarajan *et al.*, 2021). In Nigeria, these factors may intersect with poverty, rural residence and limited healthcare infrastructure, producing substantial differences in access between social groups. Services that are not culturally responsive or adequately adapted to patients' language and social circumstances may further reduce trust and discourage continued engagement with care. Overall, sociodemographic and access-related characteristics should be understood primarily as predictors of IVF utilization, treatment initiation and continuity of care, rather than as direct biological causes of implantation failure. Treatment cost, urban concentration of fertility centres, inadequate infrastructure, limited awareness, cultural stigma and shortages of trained personnel can determine whether patients are able to reach and remain within the fertility-care pathway (Chiware *et al.*, 2021; Afferri *et al.*, 2022). Public-sector funding, insurance coverage or subsidies, the development of fertility clinics into underprivileged regions, better referral systems, public education, and the integration of infertility care into larger reproductive-health initiatives are all effective ways to lessen these disparities (Karaga *et al.*, 2023; Oskowitz *et al.*, 2023). Such measures would improve not only access to IVF, but also the likelihood that patients can complete treatment and receive appropriate follow-up.

1. Recommendation

The findings of this review support an individualized and evidence-informed approach to IVF care in Benin City. Clinicians should assess each couple comprehensively rather than rely on a single predictor of implantation success. When counseling patients and making treatment plans, it is important to take into account factors such as maternal age, ovarian-reserve indicators, infertility length and reason, prior reproductive history, semen quality, endometrial thickness, uterine architecture, embryo quality, and the technical complexity of embryo transfer. Antral follicle count and AMH may be useful in determining ovarian response, but they shouldn't be used as absolute indicators of implantation or live birth. Although embryo competence and quality continue to be more therapeutically meaningful than oocyte quantity alone, the number of oocytes recovered is helpful for evaluating therapy response. Embryo selection and transfer should be conducted using clearly defined and consistently applied laboratory and clinical protocols. Fertility centres should strengthen quality assurance systems, standardize embryo grading, document embryo-developmental characteristics, and monitor transfer-related factors such as catheter passage, ease of transfer and the site of embryo deposition. A thin endometrium should be interpreted as a probabilistic risk marker rather than an automatic reason to cancel a cycle,

since implantation and live birth may still occur at lower measurements. Where implantation repeatedly fails, assessment for intrauterine pathology and other clinically relevant uterine factors should be considered. However, invasive tests and add-on procedures should be offered only when supported by a clear clinical indication and adequate evidence of benefit.

Infertility evaluation should routinely involve both partners. Women should not bear the disproportionate social and clinical burden of examinations when the reason may be male, female, or unexplained. Male-factor infertility, including defective sperm concentration, motility, and morphology, should be identified early. Clinicians should provide realistic counselling that distinguishes implantation, clinical pregnancy and live birth, while explaining the uncertainty surrounding individual prediction models. Counselling should also address the emotional, cultural, religious and financial concerns that influence patients' decisions and ability to continue treatment. At the health-system level, stakeholders should expand affordable public-sector IVF services, improve referral pathways and consider subsidies, insurance support or other financial-protection mechanisms. Fertility services should be developed beyond major urban centres where feasible, with attention to trained personnel, laboratory capacity, reliable documentation and continuity of follow-up. Public education should promote accurate information about infertility, encourage timely assessment of both partners and reduce stigma surrounding infertility and medically assisted conception. Future research in Nigeria should use prospective, multicentre designs with standardized definitions of implantation, clinical pregnancy and live birth. Studies should also validate prediction models in local populations, report relevant confounders, and distinguish biological predictors from factors that merely determine access to treatment.

2. Conclusion

Maternal traits, ovarian response, embryo competency, endometrial and uterine circumstances, transfer method, laboratory performance, and the broader clinical environment all interact to generate the multifactorial result of embryo implantation during IVF. No single variable can be used as a trustworthy predictor of success, according to the examined research. While endometrial health, embryo quality, and the technical quality of embryo transfer seem to be more important for implantation potential, maternal age and ovarian-reserve indicators are useful for treatment planning. However, a number of documented connections are based on single-center or retrospective research, and it is unclear whether they apply to women undergoing IVF in Benin City. A meaningful improvement in IVF outcomes will therefore require more than advances in embryo selection or laboratory technology. It will depend on coordinated, couple-centred care; consistent clinical and laboratory practice; early evaluation of male and female factors;

honest counselling; and improved affordability and geographic access. In Benin City and Nigeria more broadly, strengthening public fertility services and generating high-quality local outcome data are essential for ensuring that IVF is not only technically available, but also safe, equitable and responsive to the needs of the couples it is intended to help. The review consequently supports a balanced approach: clinical decisions should be personalized and evidence-based, while future research should focus on validating locally relevant predictors and linking implantation measures to the outcomes that matter most to patients, ongoing pregnancy and live birth.

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