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Permalink

<https://escholarship.org/uc/item/3d05f9nb>

Journal

Stem Cell Reports, 19(7)

ISSN

2213-6711

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Publication Date

2024-07-01

DOI

10.1016/j.stemcr.2024.05.002

Peer reviewed

Anticipating *in vitro* gametogenesis: Hopes and concerns for IVG among diverse stakeholders

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<https://doi.org/10.1016/j.stemcr.2024.05.002>

SUMMARY

In vitro gametogenesis (IVG), the reconstitution of germ cell development *in vitro*, is an emerging stem cell-based technology with profound implications for reproductive science. Despite researchers' long-term goals for future clinical applications, little is currently known about the views of IVG held by the stakeholders potentially most affected by its introduction in humans. We conducted focus groups and interviews with 80 individuals with lived experience of infertility and/or LGBTQ+ family formation in the US, two intersecting groups of potential IVG users. Respondents expressed hope that IVG would lead to higher reproductive success than current assisted reproductive technology (ART), alleviate suffering associated with ART use, and promote greater social inclusion, while expressing concerns predominantly framed in terms of equity and safety. These findings underscore the importance of sustained engagement with stakeholders with relevant experience to anticipate the implications of IVG for research and clinical translation.

INTRODUCTION

Gametes (egg and sperm) are essential for fertility. In mammals, gamete precursors, i.e., primordial germ cells (PGCs), appear early in embryonic development and undergo the complex process of gametogenesis, which spans all of embryonic, pubertal, and adult life. A recent notable development in the study of gametes is the demonstrated possibility for generation of gametes outside of the body, *in vitro* gametogenesis (IVG). IVG enters a field of discussion in which the human embryo and germline hold a widely recognized special moral value, as recently demonstrated by the discussions sparked by embryo models (Landecker and Clark, 2023; Rossant and Fu, 2023) and the debate over heritable genome editing (Rainie et al., 2022). The exploration of its social and ethical implications has become timely.

IVG leverages the technology of pluripotent stem cells, which are capable of producing all the tissues of an embryo and can be either of embryonic origin (embryonic stem cell [ESC]) or induced from cell types such as skin through reprogramming (induced pluripotent stem cell [iPSC]) (Takahashi and Yamanaka, 2006). In IVG, pluripotent stem cells are differentiated into primordial germ cell-like cells (PGCLCs). PGCLCs are then directed along pathways that PGCs follow as they develop and mature in the body. The stem cell origin of PGCLCs is particularly significant when considering the clinical applications of IVG. The

donor of the reprogrammed adult cells is the genetic origin of the iPSCs used to produce gametes, and therefore, a child born from an IVG-derived gamete would be genetically related to that donor.

Oogenesis (egg development) and spermatogenesis (sperm development) have been entirely reconstituted *in vitro* from iPSCs in mice, resulting in the birth of live and fertile offspring (Hayashi et al., 2011; Hikabe et al., 2016; Ohinata et al., 2009). In addition, a recent study reported XY to XX chromosomal sex conversion in male mouse iPSCs and subsequent *in vitro* differentiation with the generation of functional and fertilizable oocytes, thus proving the concept of same-sex reproduction (Murakami et al., 2023). Human PGCLCs have been successfully derived from both ESCs (Irie et al., 2015) and iPSCs (Esfahani et al., 2024; Sasaki et al., 2015). However, the complex process of human gametogenesis remains elusive due to ethical constraints and the restriction of human embryo culture to 14 days in most jurisdictions; human PGCs are specified at approximately 2 weeks of embryonic life. Donations of fetal tissue from abortions are sporadic and typically occur at 4–6 weeks at the earliest, when pregnancy is detectable. Further advances in human IVG are being made thanks to recent insights into human embryonic development (Wamaitha et al., 2023) and the use of nonhuman primate models as a roadmap for human development (Gyobu-Motani et al., 2023).





The proof of concept for IVG in mice, together with significant advances in human and nonhuman primates, pre-emptively profound implications for reproductive science at the same time as the reproductive potential of these cells raises ethical concerns. The International Society for Stem Cell Research (ISSCR) has acknowledged these concerns by including specific safeguards for IVG research in its guidelines such that the creation of embryos for research through IVG must be reviewed by a specialized oversight process (Category 2) and that the application of IVG to human reproduction is not permitted at this time (Category 3A) (Hyun et al., 2021). Furthermore, bioethicists have highlighted ethical, legal, and social areas of concern if IVG were to become available for clinical purposes. In addition to safety, they point to controversies around nontraditional forms of biological conception such as for same-sex couples, single individuals, or postmenopausal women; eugenics and germline engineering; and risks of abuse, e.g., by creating gametes from an individual without their consent (Bredenoord and Hyun, 2017; Cohen et al., 2017; Cutas et al., 2014; Greely, 2016; Hendriks et al., 2015; Mathews et al., 2009; Mertes, 2014; Rolfes et al., 2019; Segers et al., 2017; Smajdor and Cutas, 2015). Given the many possible implications of this research, the ISSCR, scientists, and bioethicists have also urgently called for increased engagement with the public and potential beneficiaries in order to “help to identify issues that must be addressed in order for research to be ethically sound and trustworthy” (Sugarmann et al., 2023: 420; Adashi et al., 2019; Clark et al., 2021).

Despite these concerns and even though the potential of IVG for fertility care has been emphasized by scientific and public stakeholders, there has been little empirical engagement with people representing potential users of IVG and donors of biological material to this research, in particular those experiencing involuntary childlessness due to biological or social infertility (Ishii and Reijo Pera, 2016; Lo and Campo-Engelstein, 2018; Murphy, 2014). Surveys of public and health professional views on IVG have been conducted only in the Netherlands, Belgium, the United Kingdom, and Japan (Akatsuka et al., 2021; Hendriks et al., 2017; 2018; Mertes et al., 2022). These studies reported an overall positive public view of the research, insistence on appropriate regulation and oversight, and significant cultural variation in the acceptance of reproductive use of IVG, with a lower degree acceptance reported by participants in Japan. Acceptance of the use of IVG for human reproduction was higher among respondents with self-reported infertility (Mertes et al., 2022). To date, just two studies have focused on attitudes toward IVG among a subset of infertility patients, men with azoospermia who were undergoing treatment at the time and their partners in the Netherlands (Hendriks et al., 2014; 2016). This interview-based research found that couples with azoospermia were

supportive of the concept of IVG as a treatment because it uses the patient’s own cells while being less invasive than current options, with safety and efficacy being the patients’ main concerns; “unnaturalness” and moral acceptability were of little importance to them (Hendriks et al., 2014; 2016). However, the views of women experiencing infertility and LGBTQ+ people on IVG have not been explored, reflecting the well-documented underrepresentation of such voices in matters of reproductive care and bioethics (Powell and Foglia, 2014; Vedam et al., 2019). There is no data on the perspectives of IVG stakeholders in the US. Considering the potential of IVG to “revolutionize” (Ball, 2018) and “democratize” (Testa and Harris, 2005) reproduction, further in-depth engagement with a broad range of potential users of IVG is timely.

The value of perspectives of potential beneficiaries for identifying the full range of implications of a novel technology has been demonstrated in other arenas of emerging reproductive technology. For example, Herbrand (2017) revealed a marked disconnect between the views of families with mitochondrial disease and the academic and public view of the implications of mitochondrial replacement therapies. Families with mitochondrial disease emphasized the importance of “social and medical constraints” such as cost or caring for other children when considering whether to use the therapy, highlighting that such a decision is “rarely a straightforward” one driven simply by the introduction of a technology (Herbrand, 2017: 53–54). IVG might similarly be widely assumed by scientists, medical professionals, companies, and the media to be a technological opportunity that directly addresses the needs of medically and socially infertile people. This assumption needs to be tested empirically. While no one is yet able to use IVG, the perspectives of potential beneficiaries of IVG will provide insights into the contexts in which IVG might be useful for clinical applications and the areas of opportunity and concern that should be anticipated accordingly.

Here, we address these research shortfalls by exploring the views of IVG and its potential applications to human reproduction among two overlapping groups that represent the core of potential future IVG users in the US: people with lived experience of infertility and LGBTQ+ people who have or are considering having children. These individuals possess an “experiential knowledge” that is highly relevant to anticipating IVG (Caron-Flinterman et al., 2005). By “experiential knowledge,” we mean a form of knowledge that is derived from an individual’s lived experience, which includes personal history, thoughts, emotions, bodily experiences, and relationships. Thanks to their experiential knowledge of involuntary childlessness and assisted reproductive technology (ART), these people can offer unique insights into the social and ethical implications of IVG, should it become available for reproductive purposes. Their situated



Table 1. Demographic characteristics of focus group and interview participants (n = 80)

Age (years)	
18–23	1 (1.25%)
24–35	43 (54%)
36–45	24 (30%)
46–55	7 (8.75%)
55–65	1 (1.25%)
Prefer not to answer	4 (5%)
Race/ethnicity^a	
American Indian or Alaska Native	3 (3.75%)
Asian	17 (21.25%)
Black or African American	9 (11.25%)
Hispanic	7 (8.75%)
White	42 (52.5%)
Prefer not to answer	3 (2.5%)
Gender	
Cisgender woman	53 (66%)
Cisgender man	19 (23.75%)
Nonbinary individual	4 (5%)
Transgender woman	1 (1.25%)
Transgender man	3 (3.75%)
Sexual orientation	
Asexual	2 (2.5%)
Bisexual	11 (13.75%)
Heterosexual	38 (47.5%)
Queer/gay/lesbian	29 (36.25%)
Household income	
\$0–\$30,000	10 (12.5%)
\$31,000–\$60,000	4 (5%)
\$61,000–\$90,000	20 (25%)
\$91,000–\$120,000	4 (5%)
\$120,000+	31 (38.75%)
Prefer not to answer	11 (13.75%)

^a14 participants reported more than one racial/ethnic identity. We have included here the first category that they listed.

perspective provides a necessary complement to theoretical perspectives in bioethical analysis.

The focus group and interview methodology that we used here is well suited to exploring novel considerations that a future technology might raise (Bates et al., 2005; Bollinger et al., 2021; Dasgupta et al., 2014). These qualitative instruments provide participants with open-ended questions and scenarios that allow for the raising of novel questions, views, and concerns. Participants are able to frame issues using their own words, narratives, and comparisons and to provide reasons for the opinions they express. The following analysis provides a higher level of generalization by extracting common themes and concerns from the discussions.

RESULTS

A socially diverse sample of 55 people participated in 11 focus groups consisting of individuals who had experienced involuntary childlessness, including self-identified cis-heterosexual and LGBTQ+ individuals who had or were presently undergoing fertility treatment, and LGBTQ+ individuals interested in family formation. Follow-up interviews were conducted with 17 focus group participants and 8 additional interviews with key informants in these communities. The self-reported demographic characteristics of all participants are summarized in Table 1. After being introduced to the scientific concept of IVG and how it could be used for assisted reproduction, people were asked their views about IVG (see supplemental material). Here, we report on participant views regarding potential applications to human reproduction. The results described further specifically focus on dominant themes that emerged in the dataset: systemic frustrations with existing reproductive care and family formation, hope that IVG could increase the success of ART while limiting its potential to cause pain and

Box 1. Key to quote attribution

Gender	Sexual Identity
CW: cis woman	B: bisexual
CM: cis man	A: asexual
NB: nonbinary	H: heterosexual
TW: trans woman	Q: queer, gay, or lesbian
TM: trans man	

Each attribution lists: Participant number–gender–sexual identity, as self-reported by participants. *Example:* P6-CW-H reads: participant 6, self-identified as cisgender female and heterosexual.

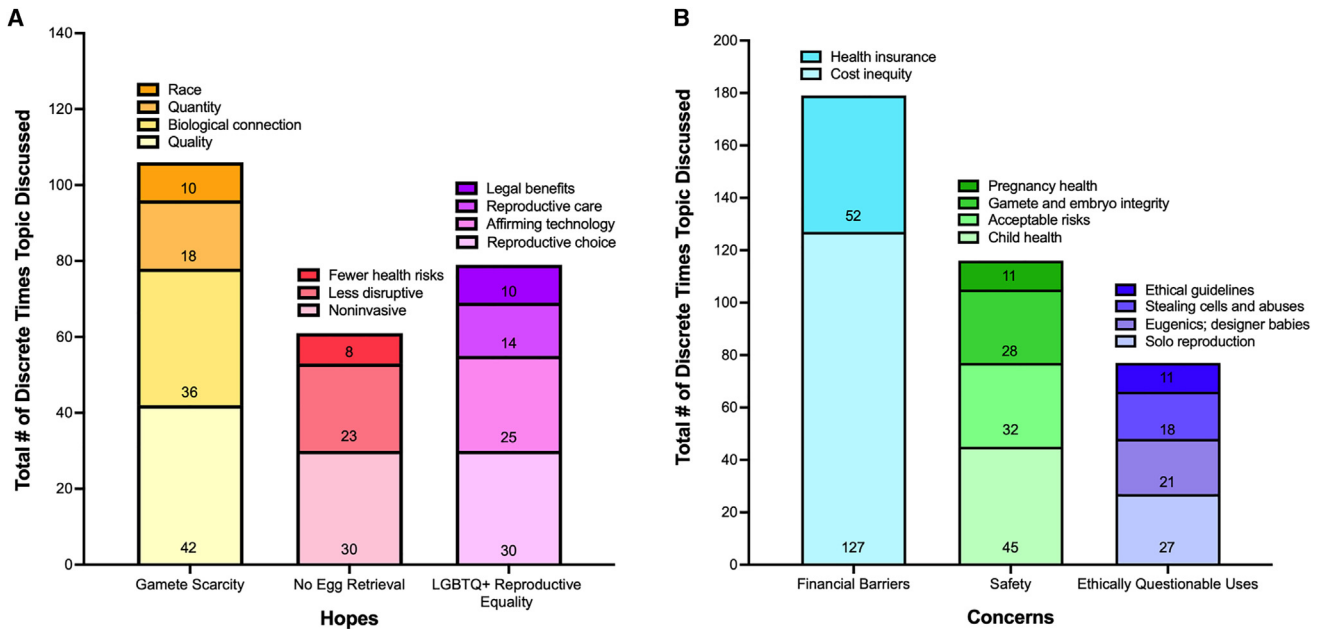


Figure 1. Total number of discrete times key topics were discussed (over 11 focus groups and 25 individual interviews) Each time involved one or more participants. (A) represents dominant hopes, and (B) dominant concerns (note that y axis scale differs between A and B).

trauma, and hope that IVG could increase reproductive justice for LGBTQ+ families (Figure 1). Concerns centered on access and safety. Representative quotes provided in the text illustrate the views expressed by participants in their own words. Self-reported gender and sexual identity of each quoted participant is indicated in parentheses (with legend in Box 1).

IVG and the limits of current ART

Here, we discuss themes highlighted by participants coming from a variety of situations, including cisgender-heterosexual and LGBTQ+ people struggling with infertility and fertile LGBTQ+ people. The quotes in the following paragraph highlight the way participants envisioned IVG's potential to facilitate the goal of having a biological child while avoiding the pain associated with egg retrieval (Figure 1A).

Addressing gamete scarcity

For people who cannot use their own gametes to have a biological child because their bodies do not produce gametes, or because they are in same-sex relationships, or because they cannot undergo egg retrieval owing to a disability, “[IVG] seems really exciting ... Well, now there’s finally an option” (P38-CW-H). Participants noted that for same-sex couples, “[IVG] is something that would represent a lot more [than IVF] because it represents, you know, ‘Oh, you can actually have a biolog-

ical child with your partner,’ which ... is so far beyond me” (P31-CW-Q).

The majority of our participants who were interested in IVG had gametes that they could use for intrauterine insemination and/or *in vitro* fertilization (IVF) but saw IVG as a technology that could help them attain higher gamete numbers and quality, and therefore better reproductive success.

I make some sperm but not nearly enough and they’re also damaged, this reduces the chance of IVF being successful ... The only chance of me being able to father a child outside of that would be looking to donor sperm. But that basically means that I’m not going to have a child that’s genetically my own, which is something that, at this point, is still really important to me. So, something like this technology that could make either more sperm or healthier sperm ... would be huge ... for someone in my situation (P29-CM-H).

Having a minimum number of both eggs and sperm is a prerequisite for creating embryos with IVF. Participants were hopeful that with IVG “you wouldn’t have that risk of not having enough” (P41-CW-H), especially for women who typically must go through several cycles of egg retrieval.

Participants also expressed hope that IVG could produce higher “quality” gametes instead of “poor eggs [and] sperm” (P75-CW-H) or that it would be “able to reverse some of that damage” (P38-CW-H) that occurs naturally in cells. “Better-quality” gametes would give people a better



chance of producing healthy embryos and having a healthy baby, while avoiding the loss and trauma associated with failing to produce an embryo or miscarrying. The specter of poor egg quality and low egg numbers weighed particularly heavily on women who often cited the cutoff age of 35 as the beginning of fertility decline. They saw IVG as “a game-changer for women”: “you don’t have to worry about egg freezing, which would be a huge benefit. ... You could just wait until you were ready [to have a baby]” (P11-CW-H).

Finally, several participants highlighted that IVG might address the needs of “the people who are not being served by sperm banks,” for example: “[We had] these three criteria. ... ‘Are you Black? Are you CMV [cytomegalovirus] positive? Are you open ID [open identity]?’ ... No one with that profile had available sperm” (P55-CW-B). The lack of gamete donors fitting certain criteria was particularly salient for racial and ethnic minorities. Thus, IVG was seen as potentially providing options in a series of situations in which people do not have gametes, whether they are absent, of poor “quality” due to age or other circumstances, or in which donor gametes do not serve aspirations about family building.

Eliminating egg retrieval

Perhaps as important as providing potential new avenues to the goal of having a biological child was participants’ enthusiastic marking of IVG as an alternative to egg retrieval, a standard practice that women and their partners unanimously described as harrowing.

I’d rather have a biopsy any day than go in for monitoring five times a week, and inject myself with hormones three times a day. ... I think honestly it just sounds pretty great, I mean, ... you don’t want to inject yourself with hormones, get put under anesthesia, or, if you’re in the worst-case scenario, not get put under anesthesia and just given pain medicine and have a needle stuck up your uterus, do your surveys through your cervix up to your uterus, to try to retrieve a bunch of eggs that there might not be a bunch. ... I really just don’t see much of a downside (P75-CW-H).

Extracting somatic cells for IVG by skin biopsy or blood draw and manipulating them outside the body was seen by participants as a less invasive and painful procedure compared to egg retrieval. Besides the surgery itself and the pain it may cause, egg retrieval today almost always involves prior hormonal stimulation, and people typically undergo several rounds of IVF. Women were unanimous in emphasizing the impact of taking large amounts of hormones on their physical and mental health. “I feel sometimes like it’s a prison where you’re just counting the shots in between and the cycles” (P69-CW-H), a situation that increases the stress that, ironically, “I can’t have ... because that affects

your egg quality” (P51-CW-H). They were also “worried” about “the long-term effects ... of injecting all of these hormones into myself so many times” (P69-CW-H) and the risk of cancer.

Women noted the imbalance of burden between providing a sperm sample and undergoing egg retrieval, “a process that is extremely unfair to the women,” and thought that IVG “could be a chance to make it a little bit more level” (P75-CW-H). Men whose partners had gone through it concurred that “mainly being able to bypass the whole egg retrieval process and all the hormones would be game-changing” (P17-CM-H).

IVG and reproductive equality for the LGBTQ+ community

While many attitudes to IVG were generally shared across all groups, LGBTQ+ participants expressed a range of views on the technology that we did not hear from our cisgender-heterosexual interlocutors. Participants talked about IVG as a potential support for LGBTQ+ people in their desire to have children and ease legal barriers to desired family formation, while also raising concerns about the possible negative consequences of IVG for LGBTQ+ families in a social context in which they do not enjoy the same reproductive rights as other families (Figure 1A).

IVG as inclusive technology

Participants quickly recognized that IVG would be the first technology that would allow a transgender person to produce a gamete that reflects their gender rather than their sex at birth and a same-sex couple to have a baby that is biologically related to both parents, and therefore could “directly benefit the queer community ... [and be] affirming” (P48-NB-Q). “The idea that both of our genetic makeup could be involved in the process is to me the most exciting part” (P44-CW-Q). Our data include many expressions of hope that IVG could support greater equity for LGBTQ+ people by providing them with a means to achieve their goal of having a biological child *if they so desire*, a goal that is shared by many people regardless of their sexual identity. Thus, a participant remarked that “IVG could definitely be the technology that maybe a lot of people have been waiting for to have access to something that heterosexual couples naturally have access to” (P76-CM-Q).

Many participants also emphasized that the queer community should not be treated as a “monolith” (P71-NB-Q) and that queer people have long been building families, “challenging all types of biological conventions” (P76-CM-Q). In that sense, they saw IVG as “another option [for] creating [a] family” that could support queer people to make their own reproductive choices (P72-NB-Q). They described a variety of social barriers related to intersecting marginalized identities (LGBTQ+ identity, socioeconomics,



race, mental health, etc.) that effectively exclude LGBTQ+ people from having children when they want to, including via ART use and adoption. “[T]here’s the barrier of being able to access [health] care in the first place, ... then to add that layer of trying to family plan in an alternative way has its own issues” (P48-NB-Q). They thought that IVG was a step in the right direction as a new path toward LGBTQ+ parenthood.

More profoundly, participants hoped that IVG technology might destigmatize LGBTQ+ parenting and families, and homosexuality more broadly, by allowing LGBTQ+ people who wish for children to have the same options as the heterosexual majority.

It’s just science catching up and becoming more inclusive ... In a certain way, I think it’s also just combating the idea of the inherent wrongness of homosexuality in certain communities. I think it’s, we’re able to have children *normally*, the world is just evolving to become more inclusive that not everyone is binary, where not everyone adheres to these ideas of what it means to be, I don’t know, a person, a good person (P63-CW-Q).

Legal implications for LGBTQ+ families

When discussing IVG, many participants pointed to legal restrictions as simultaneously an additional burden and a source of fear and uncertainty for LGBTQ+ parents. Today, while some US states allow both same-sex parents to be listed on their child’s birth certificate in place of a donor, others do not. Therefore, unlike a heterosexual parent, a gay parent who is not biologically related to a donor-conceived child must typically adopt their own child through a second-parent adoption in order to legally protect their status as a parent. Participants expressed hopes that the biological link established through IVG between both parents and the child would socially normalize LGBTQ+ families and protect them from legal challenges.

I think that it would only make things clear for same-sex couples. I mean a lot of arguments on the conservative side would say, well, they’re not biologically yours. ... I think just being able to say, “Well, they’re *literally* biologically ours, how are you going to deny parenthood?” is a great argument for a couple having children with IVG. There’s a lot of fear around that for same-sex couples (P53-CW-Q).

Genetic parenthood is recognized by family law courts as a direct pathway to legal parenthood, and IVG could provide it to same-sex parents: “With IVG ... you could literally do a paternity test or maternity test” (P78-CM-Q).

However, many participants cautioned that the technology of IVG would not, in and of itself, lead to legal equality. They expressed uncertainty about the legal meaning of IVG for queer people living within heteronormative institutions, worried in particular that IVG might indirectly un-

dermine the legal status of a queer parent who does not have a biological link to their child.

[I]f we’re able to have the technology of same-sex couples who are able to have children biologically together, will that impact the validity ... of same-sex couples that chose to have a child with a donor? ... Will the state recognize you as more of a parent, or someone that chose to have a donor as less of the parent? (P21-CW-Q).

By supporting a biological connection between both parents and their child, IVG has the dual potential effect of uplifting and undermining queer families.

Access and safety concerns

By far the concerns that generated the most discussion and emotional engagement among all participants were (1) the possibility for IVG to be financially accessible and (2) the chance of actual delivery on its promise of helping people struggling to have children. These two types of concern were brought up by participants in every single focus group discussion or interview. Participants also expressed concerns about ethically questionable uses of IVG; however, such concerns were not systematically expressed and generated much less discussion (Figure 1B).

Financial barriers to IVG

Financial issues hovered over many of the questions participants asked. “If they already don’t cover [infertility] stuff, how on earth would insurance cover it?” (P43-CW-H). “Does it just become something for the wealthy?” (P75-CW-H). Far from being an afterthought, consideration of cost and access was central to people’s thinking about IVG. While the implications varied depending on their own situation, this concern was expressed by participants regardless of their income level. Many of them emphasized that their financial concerns were specific to their location in the US and might be different in other countries. Participants described past experiences with fertility care in which they had to pay for all or part of their care, or were unable to access it for financial reasons. They noted that even when fertility care is covered by insurance, “your insurance require[s] you to go through a certain amount of, basically, procedures that [don’t] work” (P21-CW-Q). They speculated that this would mean that most people would not have access to cutting-edge reproductive technologies like IVG. Thus, in response to the suggestion that IVG might act as a reproductive equalizer, a participant offered this succinct retort: “there’s an asterisk next to that: it’s an equalizer if you’re rich” (P17-CM-H). Participants worried that socioeconomic, racialized, LGBTQ+, or other minorities would simply be excluded from accessing IVG and that IVG could even exacerbate reproductive inequalities “unless this was truly made to become actually equitable” (P71-NB-Q).



Safety

Participants viewed safety for children born through IVG as the most fundamental requirement for its use. They were primarily concerned about the ability of IVG to generate gametes that would lead to healthy embryos, a successful pregnancy, and, ultimately, a healthy baby. As such, they worried about the impact of *in vitro* protocols on the integrity of the cells: “How do you know that there won’t be some major genetic defects?” (P74-CM-Q). Others wondered if “we’re tinkering too much” (P79-CM-Q).

Notably, drawing on their knowledge of IVF and other technologies, participants worried about the subtle or difficult-to-predict effects of IVG on child development and increased disease incidence later in life.

I remember when Dolly the sheep was being cloned—that was another groundbreaking development—there were some questions about whether the cloned sheep would live a healthy and full life of a typical sheep. So, the successful pregnancy and delivering the baby is one thing, but ... because it’s so new, and kind of alien-like, will the baby’s development as a human being be impacted in any way? (P51-CW-H).

Overall, participants said that they would use IVG if the risks it presented were comparable to those of natural conception or IVF. Many participants declared that they would only be willing to use IVG after it had been proven safe in children born with IVG, or if there were long-term data on the effects of IVG in a sufficient number of cases. They remarked that “I felt safe with IVF. ... [Because] they’ve done a lot of studies at this point. They have a decent amount of people who’ve been born through IVF and for long enough” (P69-CW-H). They felt that a similar, if not identical, degree of certainty would be necessary for IVG to feel safe. Others, however, stated that “personally [I] would be willing to take that chance based on the very, very, very limited data that I have, even with that potential risk” because with reproduction “we can’t test for all of the things” (P11-CW-H).

Finally, while most discussions about safety focused on the child, many participants asked about the “risks to the mother” (P13-CW-H). They remarked that they would be unwilling to use IVG if it implied increased risks to the pregnant person, or a higher incidence of miscarriage, which they described as “traumatizing and terrible” (P11-CW-H).

Ethically questionable uses of IVG

In highlighting the predominance of the themes of justice and accessibility in participants’ discussions of IVG, we do not mean to imply that conversations about the potentially ethically questionable effects of IVG on human reproduction did not occur. In fact, many participants’ initial reactions to IVG were that it seemed “weird” (e.g., P14-CM-H), “wild” (e.g., P63-CW-Q), “unnatural” (e.g., P6-

CW-H), or even “scary” (e.g., P20-CW-Q). As with media depictions of IVG, many of them spontaneously compared IVG to works of science fiction, particularly the film *Gattaca*, which depicts a world in which genetic enhancement has become the norm for human reproduction, or *Brave New World*. Participants also spontaneously brought up several scenarios of IVG that gave them pause and that they described as raising “ethical” issues (e.g., P78-CM-Q).

First, some participants worried that IVG could be used for “eugenics” (P20-CW-Q) or “designing babies” (P70-CW-Q): “Does it lead to a slippery slope of choosing your child’s eye color or hair color, or making an embryo that is the perfect kind of embryo you want it to be?” (P45-CW-B). Second, some participants were concerned that easy access to somatic cells, especially “so easily exposed” skin cells, meant that “someone [could] theoretically take cells from someone without their consent” (P35-CW-B). “What’s to stop someone from taking a skin sample from a child, for example?” (P17-CM-H). Third, some participants expressed moral discomfort at the prospect that, with IVG “you could, in theory, just reproduce with yourself” (P9-CW-H) (a case described in the literature as “solo reproduction”), a possibility that struck participants as “scar[y]” (P4-CW-Q), tantamount to “incest” (P6-CW-H), and “something that megalomaniacs would do and ... seems like it’s more akin to cloning” (P2-CM-H).

Strikingly, such concerns about uses of IVG that participants found ethically questionable occupied little time in the overall discussions, even though participants in the focus groups and again in the interviews were explicitly asked about aspects of IVG that would give them pause. They described such potentially egregious uses of IVG as isolated abuses of the technology that required “ethical guidelines” (e.g., P44-CW-Q) and “strict criteria on who could undergo [IVG]” (P26-CM-H). However, these uses did not represent the core of IVG uses and issues that they anticipated and were eager to discuss.

DISCUSSION

This study is the first to empirically explore the views of a wide range of potential IVG users on the technology, including people with infertility and LGBTQ+ people seeking to have a child. To our knowledge, it is the first study to explore views of potential IVG users in the US. Consistent with the findings of an earlier study conducted with men with azoospermia (Hikabe et al., 2016), our participants expressed a strong interest in IVG that was grounded in their hopes that it may address the “real longing for people to be able to have children together who can’t biologically” (P20-CW-Q), experiences of pain and trauma with reproductive care, and social exclusion



from family formation. They expressed concerns about the feasibility and accessibility of IVG and the danger of false promises, noting that “people who have not gone through reproductive assistance just assume that ... you’re gonna get a baby eventually, and that doesn’t always happen” (P30-CW-H). Overall, however, they emphasized opportunity: “I think [that for] people who go through the journey and understand the loss and the pain, having these open opportunities is exciting and offers a lot of promise and hope. And I think that outweighs some of the potential issues” (P16-CM-H). In other words, the lived experience of involuntary childlessness and a path to parenthood that is increasingly constrained by treatment failure, social exclusion, or age leads individuals to emphasize the concrete opening of another path to reproduction offered by IVG (Franklin, 1997; Thompson, 2007).

It is of course to be expected that individuals already using or considering the use of assisted reproductive technologies, as our participants were, would be oriented toward thinking about how a new technology might be able to help them personally. They are able to see themselves in the shoes of future beneficiaries in a unique way. Yet what we wish to emphasize here is not a “for-or-against” binary. Indeed, what is significant about these voices is that they delineate a set of ethical and social concerns that overlap but also significantly diverge from those found in current popular media discussions of IVG, and the bioethics literature on the subject.

The bioethics literature has highlighted those “disruptive” aspects of the technology of IVG that most challenge our ethical and regulatory frameworks and therefore most clearly require ethical work (Bredenoord and Hyun, 2017; Cohen et al., 2017). In particular, while the relevance of IVG for people experiencing medical infertility has largely been taken for granted (Ishii and Reijo Pera, 2016), concerns have been raised that by “liberating parenting roles from the constraints of biological generations *in vivo*” (Palacios-González et al., 2014), IVG would open up nontraditional forms of biological reproduction, including same-sex and postmenopausal conception (Cutas and Smajdor, 2015; Murphy, 2014). For interlocutors already situated on the outside of traditional forms of biological reproduction, however, the core issue is not whether these reproductive configurations, which in many cases already exist, are ethically or socially acceptable, but how to provide a wider range of assisted choices in a safe, inclusive, and just manner.

Other themes raised in the bioethics literature to date include cells “stolen and then used, without [people’s] consent, to make gametes” (Greely, 2016: 308). Additionally, there is concern that IVG risks reinforcing the eugenic risks associated with reproductive engineering and prenatal selection (Sparrow, 2014; Suter, 2018) and “may raise the

specter of ‘embryo farming’ on a scale currently unimagined” (Cohen et al., 2017: 2). By contrast, participants who were interested in IVG because of their own experiences of struggling to have a child did not primarily view it through the lens of a dystopian future in which reproduction is engineered. Participants did discuss safety issues, but they were little concerned with scenarios such as embryo farming or illicitly generated gametes from stolen cells. Rather, they raised a set of concerns directly informed by “think[ing] about fertility on a regular basis” (P8-CW-H) and concrete experiences of facing barriers to having a child, such as low-“quality” gametes (Wahlberg, 2018) or lack of access to insurance coverage for fertility care (Bell, 2009; Resolve, 2021), experiences that directly speak to anticipations of IVG as a reproductive technology, yet in their very mundanity tend to be overlooked.

A clear example of such overlooked aspects of IVG is the emphasis placed by participants on its use as an alternative to egg retrieval. The potential of IVG to avoid the pain and trauma of egg retrieval is rarely discussed in the literature and, when it is, it is often described in medical terms as a way to avoid the extremely painful and dangerous but rare complication of ovarian hyperstimulation (e.g., Cohen et al., 2017). In contrast, our participants described egg retrieval as “horrible” (P37-CW-H) and “excruciating” (P59-CW-H) even when it goes as planned, and therefore saw IVG as of great potential benefit. People’s narratives around egg retrieval allow us to complicate the standard narrative of ART as successful when it produces a live birth, a narrative that systematically overlooks women’s experiences and obscures a key impact of IVG (Almeling and Willey, 2017; Waldby, 2019). This perspective brings important new knowledge about the potential uses of IVG and its target audience, which goes far beyond people whose bodies do not produce any gametes, to include all IVF patients.

It is clear from our participants’ discussions that IVG is not just about producing gametes. LGBTQ+ participants were largely enthusiastic about IVG’s unique ability to enable biological parenthood for same-sex couples. However, they also emphasized the nuanced and multifaceted impacts of IVG on LGBTQ+ families, often overlooked in public discussions of IVG. They described experiences of social and legal exclusion against which IVG might become relevant. LGBTQ+ parents today face experiences of stigmatization in raising nontraditional families (Gartrell et al., 2019) and unique legal challenges in divorce cases (Goldberg and Romero, 2018) or with donor gametes (Joslin, 2023). For these participants, the critical feature of IVG is its potential to be socially and legally inclusive for LGBTQ+ families. In their view, it could advance equity not only by providing a technological means to have a biological child, but also more profoundly by supporting LGBTQ+ people’s ability to choose how and



when to have (or not have) children, and the inclusion of LGBTQ+ families more broadly.

The opportunities and concerns raised by participants point to the importance of reproductive justice considerations when thinking about an emerging reproductive technology such as IVG (Horn, 2023). The concept of “reproductive justice” was first coined by Black women activists in 1994, who understood that primarily White-women-led fights for “reproductive rights,” that is, the ability to have or not have a child as one chooses, could not be realized without addressing the unjust economic, social, environmental, mental, and physical conditions that Black, Indigenous, and other marginalized peoples endured (Ross and Solinger, 2017; Silliman et al., 2016). In this same vein, our participants, who experienced a lack of functional gametes alongside socioeconomic or legal barriers to parenting a child, emphasized that IVG must meet not only the requirements of functionality and safety, but also the tenets of reproductive justice in order to address their reproductive needs in the future.

Importantly, some of our participants highlighted that these very barriers present immediate obstacles to genuine public engagement with stem cell science. Participants emphasized the “emotional labor” (P63-CW-Q) that is required to participate in a study about such intimate and sensitive topics, a labor that was compensated in the same way for all participants regardless of personal situation and despite the additional burden experienced by populations historically subjected to reproductive violence. Participants also voiced a “mistrust around the medical industrial complex, Western science, and colonialism” (P72-NB-Q) due to sordid histories of racialized abuse and neglect in biomedical research. Finally, despite their interest in the topic, many of our interlocutors from underserved communities explained that they could not devote mental, emotional, or organizational resources to thinking about IVG when they faced much more pressing concerns such as high rates of pregnancy-related death among Black and Indigenous birthing people (Fleszar et al., 2023), or the difficulty many trans people have in simply accessing basic needs such as food, housing, and health care (Conron and O’Neill, 2022; Jordan, 2024). As some of our interlocutors pointed out, it is critical for the scientific and bioethical community to address these barriers by involving advocates early on as well as building community engagement resources into the budget and design of IVG research, rather than simply seeking to extract diverse viewpoints on topics distant from more urgent concerns.

The in-depth qualitative data discussed here identify novel points of interest in and concern for IVG among potential beneficiaries. Future empirical studies should compare our findings to attitudes toward IVG among other groups of potential users, such as oncofertility patients

(Mertes and Pennings, 2022; Wesevich et al., 2023), and the general public. This qualitative data also paved the way for larger survey-based quantitative studies that could examine the generalizability of these findings in a larger population sample. While our study intentionally sought to construct a diverse pool of respondents, its scope is limited by the overrepresentation of individuals with high income and education levels and/or who identified as White and female. This is consistent with the demographics of ART use in the US, which is severely limited by financial barriers (Sunderam et al., 2022; Tierney and Cai, 2019) and exacerbated by racial disparities (ASRM, 2021; Quinn and Fujimoto, 2016; Weedin et al., 2017).

In conclusion, this study provides scientists and scholars with the experiential viewpoint of potential beneficiaries of IVG in a variety of situations and suggests avenues for public engagement about IVG that have received little attention. The perspectives of potential beneficiaries, grounded in lived experience, provide valuable insight into future real-world uses of IVG and concerns raised by this technology and the related fields of embryo and germline research. Our data show that issues of equity and access to reproductive care and family formation are central rather than secondary to potential IVG users and suggest that these issues should be foregrounded in discussions of the social and ethical implications of IVG. By highlighting gaps between the views of potential users and key themes in the scholarly and media debate about IVG, our study draws attention to the importance of sustained public engagement through empirical studies and other means to ensure the inclusion of all IVG stakeholders in this debate.

EXPERIMENTAL PROCEDURES

Resource availability

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Materials availability

Focus group educational materials are provided in the supplementary materials. Interview guides are available upon request.

Data and code availability

This study did not generate new datasets.

Focus groups

We conducted focus groups and semi-structured interviews with two groups of individuals, not mutually exclusive, who could potentially utilize IVG in the future: people with lived experience of infertility and fertile LGBTQ+ people seeking to form a family. This study was approved by UCLA’s Institutional Review Board



(Protocol #21-001281) and followed the Transgender Research Informed Consent disclosure policy.

11 focus groups including 3 to 7 participants were moderated by two team members of our interdisciplinary research team (A.L., R.J.H., A.N.H., and I.R.) between March and August 2023. Moderators first led a PowerPoint presentation to explain in ordinary terms the scientific concept of IVG to participants and how IVG could potentially be used with IVF for reproduction in the future. This was followed by a discussion in which participants were asked to explore and share their views on aspects of IVG. Focus group discussions follow a predetermined set of topics while leaving room for participants to raise new questions and considerations (Liamputtong, 2011). The discussion first addressed issues of research with gametes and embryos, on which we do not report here. Two hypothetical case scenarios were then proposed to participants to explore clinical uses of IVG. Finally, participants were invited to discuss social and political concerns around IVG access and acceptability. Focus groups lasted approximately 90 min.

Interviews

Follow-up interviews with selected participants were held between May and September 2023 (R.J.H., A.L., and A.N.H.). Interviewees were asked to further describe their views and concerns about IVG in relation to their personal experiences around family formation. Interviews lasted 1 h to 90 min. Both focus groups and interviews were conducted by Zoom video conferencing, with participants located across the US. Participants were provided with consent forms and financially compensated for their time.

Transcript analysis

Interviews and focus groups resulted in 42 h and 44 min of recordings. Following a grounded theory approach (Charmaz, 2013; Glaser and Strauss, 1967), we analyzed the transcripts to identify novel questions and themes raised by participants. This approach provides the analyst with systematic steps for inductively and iteratively generating interpretative codes and identifying emergent themes during the research process. (a) Two team members (A.L. and R.J.H.) independently performed several readings of the transcripts and generated a list of interpretative categories. (b) They compared these categories, resolved discrepancies, and jointly generated a new list of codes and themes. (c) This codebook was used to code all the transcripts and identify and analyze core themes. Quotes were selected for their representativity and ability to illuminate a question in a participant's own words. Additional information about the study's methodology is provided in the Supplemental information.

SUPPLEMENTAL INFORMATION

Supplemental information can be found online at <https://doi.org/10.1016/j.stemcr.2024.05.002>.

ACKNOWLEDGMENTS

Research reported in this publication was supported by the National Human Genome Research Institute of the US National Institutes of Health, grant #R21HG012248. A.N.H. was also supported by the Robert Wood Johnson Foundation Health Policy Research Scholars

Program. I.R. was supported by the National Institute of General Medical Sciences of the US National Institutes of Health, award #T32GM145388. In addition, this research was supported by the National Center for Advancing Translational Sciences of the U.S. National Institutes of Health, grant #UL1TR001881. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

The authors thank Amisha Gadani for developing visual materials for the study and Emily Baghrmian, Alexis Baughman, Andres Ceja, Rachel Kho, Autumn Jackson, Grace Park, Alma Rincongallardo, Natalie Rodgers, and Taylor Webb for their research assistance. Thanks also to Amander Clark and the members of the UCLA Clark laboratory, Michelle Rensel, the UCLA Center for Reproductive Science, Health and Education, the fellows of the UCLA Institute for Society and Genetics, and the UCLA Clinical and Translational Research Center for insights and comments.

AUTHOR CONTRIBUTIONS

A.L.: conceptualization, methodology, investigation, data curation, writing – original draft, writing – review and editing, project administration, and funding acquisition. R.J.H.: conceptualization, methodology, investigation, data curation, and writing – review and editing. A.N.H.: methodology, investigation, and writing – review and editing. I.R.: investigation and writing – review and editing. H.L.L.: conceptualization, methodology, writing – review and editing, supervision, project administration, and funding acquisition.

DECLARATION OF INTERESTS

The authors declare no competing interests.

Received: November 7, 2023

Revised: May 7, 2024

Accepted: May 8, 2024

Published: June 6, 2024

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