Challenges experienced by genetic counselors while they provided counseling about mosaic embryos

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Objective: To survey genetic counselors (GCs) who have counseled about mosaic embryos regarding the challenges they faced in counseling this patient population and assess their need for more resources to support their practice.
Design: Self-administered online survey.
Setting: Academic university.
Study Population: Seventy-eight GCs primarily from the United States and Canada.
Intervention(s): Genetic counselors completed a quantitative survey with an embedded qualitative component. Quantitative data were analyzed by descriptive statistics. An inductive thematic analysis was performed on open-text responses.
Main Outcome Measure(s): Genetic counselors were asked what clinical activities relating to mosaic embryos they performed. They were then asked to rate how challenging each activity was to perform using a 5-point scale; a rating of 4 or 5 was defined as highly challenging. Open-text questions enabled GCs to describe factors that they felt contributed to these challenges.
Result(s): The challenges reported by GCs included the uncertainty of outcomes in offspring after mosaic embryo transfer, limited guidelines available to assist clinicians with counseling about mosaic embryos, and ranking mosaic embryos by suitability for transfer. The contributing factors suggested by participants included limited outcome data, limited GC involvement in pretest counseling for preimplantation genetic testing for aneuploidy (PGT-A), and perceived inconsistency in counseling practices across clinics. Genetic counselors differed in their genetic testing recommendations for pregnancies conceived after mosaic embryo transfer. Amniocentesis and postnatal assessment were recommended by 85% and 49% of GCs, respectively, and 15% recommended chorionic villus sampling and noninvasive prenatal testing. Almost all (92%) reported a need for more resources, such as standardized guidelines, more outcome data, and continuing education on PGT-A and mosaicism.
Conclusion(s): This study describes challenges experienced by GCs while they counseled about mosaic embryos. Our findings demonstrate a need for more outcome data on mosaic embryo pregnancies and for evidence-based clinical guidelines. The differing recommendations for prenatal genetic testing among GCs in the study warrant further research into contributing factors. We strongly recommend that pretest counseling, including a discussion regarding mosaicism, is provided to all couples considering PGT-A to reduce counseling challenges and to promote patients' informed decision-making. (Fertil Steril Rep® 2023;4:353–60. ©2023 by American Society for Reproductive Medicine.)
Key Words: Mosaic embryos, preimplantation genetic testing, IVF, genetic counseling

Preimplantation genetic testing for aneuploidy (PGT-A) is a practice used by in vitro fertilization (IVF) clinics in an effort to maximize implantation and live birth rates (1, 2). Current PGT-A technology involves screening a sample of trophectoderm cells in blastocyst embryos for aneuploidy (2). Recently, next-generation sequencing–based PGT-A has complicated embryo selection due to its ability to identify embryos with chromosomal mosaicism, which contain both euploid and aneuploid cell lines (1). Approximately 3%–20% of all blastocysts that undergo next-generation sequencing–based PGT-A are reported as mosaic (3). Importantly, PGT-A is not a diagnostic test and assumes that a trophectoderm biopsy is reflective of the entire embryo. Studies comparing the chromosomal copy number of samples from the trophectoderm and inner cell mass demonstrate good concordance in embryos that are deemed euploid or aneuploid by PGT-A; however, concordance is lower in

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embryos identified as mosaic (reviewed by Viotti (4)). Other factors influencing PGT-A results include variability in biopsy techniques and test artifacts from deoxyribonucleic acid amplification or sequencing (4, 5). Despite these limitations, PGT-A is performed for clinical use, and the results obtained from PGT-A, including mosaic findings, are being used to inform embryo transfer decisions. Mosaic embryo transfer (MET) was first reported by Greco et al., in their description of 6 healthy newborns after transfer of 18 mosaic embryos at a single fertility clinic (33% live birth rate) (6). To date, hundreds of healthy infants have been born after MET (6–9).

Although available MET data are encouraging, risks and uncertainties associated with mosaic embryos remain, which complicate the counseling and management of IVF patients and children born after MET. If an ongoing pregnancy is achieved after MET, the most likely outcome is a newborn with a normal karyotype (1, 5, 10). However, there is the rare possibility of a newborn with a mosaic or aneuploid karyotype (11, 12). Furthermore, fetal mosaicism is impossible to definitively rule out, and if it is confirmed, phenotypic effects are difficult to predict (13). At this time, the short- and long-term health outcomes of children born from mosaic embryos involving different chromosomes, types of mosaicism (segmental vs. whole chromosomes), and levels of mosaicism (% aneuploid) are unknown (14–16). Additionally, prior literature suggests that uptake of diagnostic testing among pregnancies conceived with euploid embryos or untested embryos (no PGT-A used) is low (17, 18). It is also uncommon for apparently healthy newborns to undergo postnatal testing (4). Therefore, it is unclear whether children conceived after MET have different outcomes compared with children conceived from untested or euploid embryos.

Limited resources are available to guide clinicians with the counseling and management of mosaic embryos. Professional bodies have published committee opinions regarding the clinical management of mosaic results obtained from PGT-A (3) and guidelines for ranking mosaic embryos by suitability for transfer; but, most of these guidelines were based on theoretical risks (19–21). Recent publications have reported on obstetric outcomes for over 1,000 METs (8, 22); however, the long-term medical and developmental outcomes of children conceived after MET, and whether these outcomes differ from children conceived from euploid or untested embryos, remain unknown. Additionally, there are few publications outlining pre- and posttest genetic counseling considerations for PGT-A (1, 3). Although these publications echo recommendations for prenatal diagnostic testing for mosaic embryo pregnancies previously reported by others (19, 23, 24), none of the available guidelines regarding the genetic counseling and management of mosaic embryos were informed from clinical practice.

Genetic counselors (GCs) are clinicians with training in both medical genetics and counseling and are highly skilled in assisting patients with understanding and adapting to the implications of genetic contributions to disease (25, 26). In fertility settings, patients considering PGT-A or MET may be referred for genetic counseling, where GCs discuss the benefits, limitations, and possible outcomes and are expected to help patients decide how to proceed. One prior study by Besser et al. evaluated patient decision-making regarding their mosaic embryo(s) after receiving genetic counseling (14). To our knowledge, no studies have directly evaluated the experiences of GCs who provide genetic counseling for mosaic embryos. It is unknown whether GCs experience challenges while providing counseling about mosaic embryos. Given the growing interest in MET, as shown by a survey of fertility clinics in the United States (27), it is timely to capture the clinical activities and resource needs of GCs who counsel about mosaic embryos in preimplantation, prenatal, and postnatal settings. This study aimed to survey GCs with experience counseling about mosaic embryos regarding the clinical activities they performed, the challenges they faced while providing this counseling, and whether they needed more resources.

MATERIALS AND METHODS

Study Population

The current members of the National Society of Genetic Counselors (NSGC) and Canadian Association of Genetic Counsellors (CAGC) were emailed survey invitations. Eligible participants included GCs with self-declared experience with counseling about mosaic embryos. Four reminder emails were sent to members throughout December 2020 to February 2021. Snowball sampling was implemented to invite GCs who were not NSGC or CAGC members. This study was approved by the Institutional Review Boards of the Hospital for Sick Children, Mount Sinai Hospital, and the University of Toronto.

Data Collection

Participants completed a self-administered online survey using Research Electronic Data Capture, which securely collects data for research (28, 29). Participants provided consent by reviewing consent information and clicking an "I consent" checkbox before accessing the survey. The survey contained 65 items that were a combination of closed-ended, open-ended, and ranking-style questions. Participants confirmed that they were GCs and were asked whether they had experience counseling about mosaic embryos at the start of the survey. In addition to collecting demographic information, the survey used a nonvalidated tool to assess the participant's familiarity with mosaic embryos by the completion of 10 knowledge-based questions. The knowledge questions covered various themes relating to PGT-A and mosaic embryos on the basis of published guidelines and literature (Supplemental Table 1, available online). A familiarity score was calculated for each participant on the basis of the number of correct responses. We also assessed the participant's awareness of mosaic embryo-related resources and guidelines that were available at the time of survey circulation (Supplemental Table 2, available online) (30, 31).

The survey asked participants to report in which setting(s) they provided counseling about mosaic embryos (preimplantation, prenatal, and postnatal) and approximately how many mosaic embryo cases they counseled.

TABLE 1

Characteristics of genetic counselors who have counseled about mosaic embryos (n = 78).

Characteristic	N (%)
Setting in which they counseled about mosaic embryos[a]	
Preimplantation	64 (86)
Prenatal	47 (69)
Postnatal	4 (5)
Mean number of mosaic embryo cases in current or previous role(s)	
1–2 per mo	51 (66)
3–5 per mo	11 (14)
6–9 per mo	5 (6)
≥10 per mo	11 (14)
Total number of mosaic embryo cases, mean (range)	61 (1–1,000)
Worked in a fertility clinic	
Ever	35 (45)
Never	43 (55)
Country of employment	
Canada	18 (23)
United States	57 (73)
Other country	3 (4)
Year of graduation, median (range)	2015 (1988–2020)
Professional organization membership	
NSGC	55 (71)
CAGC	13 (17)
Both NSGC and CAGC	9 (11)
Other professional organization	1 (1)

CAGC = Canadian Association of Genetic Counsellors; NSGC = National Society of Genetic Counselors.
[a] Participants could select more than 1 item; thus, proportions may not add to 100%.

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TABLE 2

Clinical activities performed by GCs who counseled about mosaic embryos in preimplantation and prenatal settings.

Activities included in role (yes)	N (%)
GCs who counseled in preimplantation settings	**64**
Provided pretest counseling for PGT-A	32 (51)
Provided posttest counseling after PGT-A	55 (87)
Disclosed PGT-A results, including mosaic findings	25 (46)
Interpreted PGT-A results, including mosaic findings	42 (76)
Discussed possible pregnancy outcomes of MET on the basis of PGT-A results	55 (100)
Facilitated patients' decision-making (i.e., to consider MET, cryopreserve or discard embryos, and/or undergo another IVF cycle)	45 (82)
Helped rank mosaic embryos for transfer on the basis of specific PGT-A results	35 (64)
Discussed prenatal screening and prenatal diagnosis options	53 (96)
Facilitated referral to a prenatal genetics clinic	15 (27)
Discussed postnatal assessment	26 (47)
GCs who counseled in prenatal settings	**47**
Counseled about possible pregnancy outcomes after MET	43 (92)
Testing options GCs recommended to patients pregnant after MET	
Amniocentesis	40 (85)
Chorionic villus sampling	6 (13)
NIPT	7 (15)
Postnatal assessment	23 (49)
Other	4 (9)

GC = genetic counselor; IVF = in vitro fertilization; MET = mosaic embryo transfer; NIPT = noninvasive prenatal testing; PGT-A = preimplantation genetic testing for aneuploidy.

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To assess challenges experienced by GCs, participants were presented with a list of clinical activities and counseling points relating to mosaic embryos. Participants were asked to select which activities they performed and which counseling points they addressed in their counseling. Participants were then asked to rank the activities and counseling points on the basis of how challenging they were to perform using a 5-point Likert scale. We defined items ranked as 4 or 5 as highly challenging. Finally, participants were asked whether they require resources to support their counseling about mosaic embryos and, if so, what resources they prefer.

The survey was designed using expert opinion and clinical experiences of the study team members working in fertility, prenatal, and pediatric genetics. The survey was trialed by 3 external GCs to assess comprehensibility and feasibility. These GCs worked in fertility, prenatal, and pediatric genetics clinics and in both private and public practices. Feedback from the trialing process was incorporated into the survey before circulation.

Statistical Analysis

Descriptive statistics were used to describe study participants. Frequency analyses were performed to assess survey responses. All analyses were conducted using R software (version 4.0.5) (32). Open-text questions were included to allow participants to elaborate on responses. An inductive thematic analysis was performed on open-text responses to minimize bias when identifying common themes.

RESULTS

We received 85 survey responses. Seven surveys were incomplete; thus, 78 participants were included. The baseline characteristics are described in Table 1. Most participants saw 1–2 mosaic embryo cases per month (66%) and worked in the United States (73%). Almost half (45%) reported experience working in a fertility clinic. Twenty (26%) were the only GCs who counseled about mosaic embryos in their clinic.

Thirty-one GCs (37%) reported counseling about mosaic embryos in preimplantation settings only, 14 (17%) in prenatal settings only, and 33 (40%) in both preimplantation and prenatal settings. Four GCs (5%) also counseled in postnatal settings; because of the small sample size, only clinical activities and counseling challenges experienced by GCs in preimplantation and prenatal settings are reported. The mean familiarity score regarding PGT-A and mosaic embryos was 7.9 of 10 (Supplemental Table 1). Mosaic embryo resources,

FIGURE 1

Preimplantation settings	Prenatal settings
1. Uncertainty of outcomes in babies born following MET	1. Limited MET outcome data
2. Limited MET guidelines and resources	2. Uncertainty of outcomes in babies born following MET
3. Ranking mosaic embryos based on PGT-A results	3. Facilitating decision-making regarding outcome of a pregnancy determined to be mosaic or aneuploid by prenatal screening/testing
4. Facilitating MET decision-making with patients	4. Supporting patients as they cope with the uncertainties of achieving a livebirth
5. Discussing pros and cons of proceeding with MET	5. Conflicting results between PGT-A and prenatal diagnostic testing
6. Interpreting PGT-A results	6. Explaining the biological basis of chromosomal mosaicism to patients
7. Discussing PGT-A results with patients	7. Identifying prenatal screening and testing options to screen for mosaicism in the fetus
8. Consulting published guidelines to identify mosaic embryos suitable for transfer	8. Facilitating decision-making regarding prenatal screening/ testing
9. Introducing chromosomal mosaicism as a possible outcome for PGT-A to patients	9. Increased chance of miscarriage associated with MET
10. Explaining the biological basis of chromosomal mosaicism to patients	10. Interpreting results from prenatal screening/testing
11. Discussing the increased chance of miscarriage associated with MET	

Challenges experienced by genetic counselors while they provided counseling about mosaic embryos. The items are listed in order from most often ranked as highly challenging to least often ranked as highly challenging to perform among participants. "Highly challenging" was defined as selecting 4 or 5 on the corresponding Likert scale. MET = mosaic embryo transfer; PGT-A = preimplantation genetic testing for aneuploidy.

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guidelines, and relevant literature consulted by study participants are shown in Supplemental Table 2.

Clinical Activities Performed by GCs in Preimplantation Settings

Among the 64 GCs who counseled in preimplantation settings, 32 (51%) provided pretest PGT-A counseling (Table 2). Most (87%) provided posttest counseling. Topics covered in posttest counseling varied; however, all discussed possible outcomes after MET on the basis of specific PGT-A results. Other activities performed during posttest counseling included discussing prenatal screening and diagnosis options (96%) and facilitating patients' decision-making on how to proceed with their IVF cycle (82%). Sixty-four percent of GCs helped rank mosaic embryos for transfer on the basis of the chromosome(s) involved in the mosaicism. Forty-six percent of GCs who provided posttest counseling also disclosed PGT-A results.

The 32 GCs who did not provide pretest PGT-A counseling reported that this was performed by physicians (n = 13), nurses (n = 6), and other GCs (n = 4) (not shown). In the open-text data, 5 of these GCs explained that local fertility clinics provided pretest counseling and disclosed PGT-A results. After disclosure, patients were referred for genetic counseling at the clinic's discretion.

Clinical Activities Performed by GCs in Prenatal Settings

Clinical activities performed by GCs who counseled about mosaic embryos in prenatal settings are shown in Table 2. Most GCs (92%) discussed potential pregnancy outcomes after MET, and 96% discussed prenatal testing options with patients who became pregnant after MET. Specific testing options recommended to patients who were pregnant after MET included amniocentesis (85%) and postnatal assessment (49%). Noninvasive prenatal testing (NIPT) and chorionic villus sampling (CVS) were recommended by 15% and 13% of GCs, respectively. Other testing options reported in open-text responses included detailed fetal ultrasound and fetal echocardiogram.

Challenges Experienced by GCs While They Counseled About Mosaic Embryos

Most GCs who counseled in preimplantation settings (95%) provided complete information on the challenges they experienced (Fig. 1). The activities and counseling points that were most often ranked as highly challenging were the following: the uncertainty of short- and long-term outcomes in offspring born after MET; limited guidelines available to assist clinicians with mosaic embryo cases; and the task of ranking mosaic embryos for transfer.

Most GCs who counseled in prenatal settings (96%) provided complete information on the challenges they experienced (Fig. 1). The activities and counseling points that were most often ranked as highly challenging were the following: the limited outcome data of pregnancies conceived by MET; the uncertainty of short- and long-term outcomes in offspring born after MET; and facilitating decision-making regarding the outcome of a pregnancy with confirmed mosaicism or aneuploidy. The full data set of challenges experienced by participants is shown in Supplemental Table 3 (available online).

Thematic Analysis

Thirty-seven GCs (47%) provided open-text responses elaborating on factors that they felt contributed to the challenges

they faced when counseling about mosaic embryos. Twenty (54%) described the limited outcome data, uncertainty of successful MET, and lack of health outcomes as the most common contributing factors. Illustrating this theme, one participant wrote the following:

> "The decision to transfer a mosaic embryo is extremely emotionally charged, especially if it is the couple's only option to try to have a biological child. The lack of outcome data and evidence-based guidance for prioritizing mosaic embryos is very challenging, especially as many of the couples undergoing IVF are highly educated, information-seeking types of patients." *(Participant 26, preimplantation and prenatal settings)*

Ten GCs (27%) cited perceived misinformation about PGT-A and mosaicism at both the patient and physician levels as a challenge. One participant described the misinformation patients may acquire through their own research:

> "I have encountered many patients who are very motivated to have an embryo transfer. They often find online groups/resources that over-simplify the concerns with mosaic embryos and can give patients a false understanding of their results." (*Participant 194, preimplantation setting)*

Another GC elaborated on perceived misinformation that may occur within IVF clinics:

> "… Many patients seem to have been told by their IVF center that CVS is adequate to determine if mosaicism is present particularly because it is an earlier procedure without consideration of cell type. Many patients seem to think that if they are pregnant then the mosaicism is not a problem in the current pregnancy, and that the risk they had focused most on prior to transfer was the chance they would not become pregnant or would have an early miscarriage. It seems there is often less focus on the possible outcomes prior to transfer including true fetal mosaicism in an ongoing pregnancy or in a child." *(Participant 118, preimplantation and prenatal settings)*

Eight GCs (22%) described not being involved in pretest PGT-A counseling, which they felt led to challenges when counseling patients after PGT-A or MET. One participant commented the following:

> "It was difficult to see patients after they had already chosen to transfer a mosaic embryo and had not seen a GC or were [not] counseled on the situation before choosing an embryo. This was frustrating and complicated in several instances where we felt the patient was not fully aware of the outcome. We saw a couple that had chosen to implant an embryo which was mosaic and positive for Trisomy 21. It would have been a smoother process if we had the opportunity to speak with them before they did IVF." *(Participant 72, preimplantation and prenatal settings)*

A fourth theme that emerged was perceived variation across fertility clinics and PGT-A laboratories regarding mosaicism, as reported by 6 (16%) GCs and described in the following quotes:

> "… A lack of consensus in the field, I find it especially challenging that labs are setting their own standards for reporting mosaicism, so some clinics will use labs who don't report mosaic results at all. This doesn't seem right to me that this is being decided by the labs instead of the patients/providers/community." *(Participant 4, preimplantation and prenatal settings)*

> "The lack of communication and guidelines for REI [Reproductive Endocrinology and Infertility] clinics in recommending genetic counseling before MET is the most challenging part. It is frustrating that each clinic has its own policies and recommendations, and sometimes GCs have to educate patients after the transfer has already taken place." *(Participant 72, preimplantation and prenatal settings)*

The Need for More Resources Among GCs

Almost all GCs (92%) reported needing additional resources to support their practice (Supplemental Table 4, available online). Standardized guidelines to assist with counseling about mosaic embryos were the most frequently desired resource (76%). Other desired resources included more research and literature on outcome data (71%) and webinars regarding mosaicism, PGT-A, and prenatal and postnatal care (63%).

DISCUSSION

To our knowledge, this is the first study to describe clinical activities performed by GCs while they counseled about mosaic embryos in preimplantation and prenatal settings, explore the challenges they experienced, and assess desired clinical resources.

Although our sample was small, our results showed that only half of the GCs who counseled in preimplantation settings provided pretest PGT-A counseling. Even fewer disclosed PGT-A results. As suggested by participants, variation in pre- and posttest counseling practices observed among GCs may be at the discretion of fertility clinics and multidisciplinary approaches to patient care. On what basis fertility clinics referred patients for genetic counseling before or after PGT-A was beyond the scope of this study but warrants further exploration.

Our findings revealed inconsistency among the prenatal tests recommended to patients pregnant after MET. Most GCs (85%) reported recommending amniocentesis after MET. Although fetal mosaicism cannot be ruled out definitively, amniocentesis is recommended because it directly samples fibroblasts from the fetus (1, 20, 33). Interestingly, 3 (6%) of the GCs in our study recommended CVS, 4 (9%) recommended NIPT, and 3 (6%) recommended both CVS and NIPT to patients pregnant after MET. The American College of Obstetricians and

Gynecologists named CVS (in addition to amniocentesis) as an acceptable option for mosaic embryo pregnancies in their recent Committee Opinion (33); however, CVS is limited in screening for fetal mosaicism because it samples placental cells, which are derived from the same cell population screened by PGT-A (13, 24). Although NIPT can be considered in a mosaic embryo pregnancy according to the Preimplantation Genetic Diagnosis International Society Position Statement (20), this test analyzes cell-free deoxyribonucleic acid from placental cells and is not validated to detect mosaicism (13). Finally, half of the GCs who counseled in prenatal settings recommended postnatal assessment. Postnatal genetic testing via karyotyping or chromosomal microarray has been suggested to track outcomes in newborns born after MET (1, 3). Although not directly ascertained in our study, this variability in practice may be due to internal clinic policies. Considering the novelty and theoretical risks associated with MET, consistency in genetic counseling and prenatal testing recommendations are important for standardized patient care.

Several counseling challenges experienced by GCs emerged from open-text data. The most frequently described challenge was the paucity of outcome data associated with MET. Despite recent publications focused on obstetric and neonatal outcomes after 1,000 METs (5, 22), evidence is still limited regarding health and developmental outcomes of infants and children conceived from mosaic embryos and whether these outcomes differ from live births conceived via euploid or untested embryos.

Another challenge cited by GCs was their limited involvement in pretest PGT-A counseling. As per the NSGC's Code of Ethics, GCs provide pretest counseling to "enable their clients to make informed decisions, free of coercion, by providing or illuminating the necessary facts, and clarifying the alternatives and anticipated consequences" (34). The uncertainty and burden of PGT-A and/or MET decision-making may add to the psychological burden already experienced by IVF patients (1, 35). Furthermore, there is literature demonstrating that some IVF patients may not understand the capabilities, limitations, and results obtained by PGT-A (36, 37). Thus, GCs are uniquely positioned to provide PGT-A education, ensure patient understanding, and facilitate PGT-A and MET decision-making through their advanced training in patient education and counseling techniques. As previously recommended (1), pretest counseling for PGT-A should address the benefits and limitations and risks and uncertainties associated with mosaicism before PGT-A to promote informed decision-making. If adequate genetic counseling is not provided to a patient before PGT-A, GCs and other clinicians may be placed in challenging situations when counseling patients post-MET. Such scenarios are not ideal for informed decision-making or patient care.

Genetic counselors also reported perceived misinformation about mosaicism, such as the associated risks and optimal methods to screen prenatally for mosaicism. Misinformation may be damaging to couples considering MET because the risks associated with mosaicism may come across as minimal. As demonstrated by the open-text data, GCs described scenarios where patients were shocked by the information provided during post-MET genetic counseling. These experiences reinforce the need for pretest PGT-A counseling, ideally by GCs, to include the implications of mosaic findings.

Finally, GCs faced challenges with inconsistency in how mosaicism was reported. On top of the known limitations in PGT-A technology and validity for predicting mosaicism (4, 16), there is no consensus on how mosaicism should be defined by PGT-A laboratories, although a commonly accepted threshold is 20%–80% aneuploidy in sampled trophectoderm cells (19, 20). A survey of MET practices among 252 fertility clinics in the United States showed variation in the thresholds used by PGT-A laboratories to define embryos as mosaic (27). In addition, only 91 (36%) of participating clinics reported receiving mosaicism data (27), suggesting that most PGT-A laboratories cannot report mosaicism because of testing technology or choose not to. Patients and providers across fertility clinics may also have the option to accept or decline to receive mosaic findings and/or to choose specific mosaicism reporting schemes. Overall, this variability in practice may contribute to challenges in establishing evidence-based guidelines for the counseling and management of mosaic embryos. Our study also suggests inconsistencies in referrals to GCs across fertility clinics.

Almost all GCs desired more resources to support their practice, including more outcome data and standardized guidelines for the counseling and management of mosaic embryos. Given that GCs are expected to discuss mosaic findings and facilitate patient decision-making regarding MET, the challenges experienced by GCs due to the paucity of guidelines and resources may represent a practical dilemma for them. Moreover, the reported challenges and desired resources among GCs suggest a lack of a standardized approach in the reporting of mosaicism and in genetic counseling practices across fertility and prenatal clinics, including recommendations for prenatal testing in mosaic embryo pregnancies. Most importantly, there continues to be a need for more MET outcome data including prenatal and postnatal assessments for mosaicism and other chromosomal anomalies, as well as, tracking of health and developmental outcomes among larger cohorts. Until such data are made available, any subsequent mosaic embryo guidelines that are developed will continue to be based on expert opinion and theoretical data. It is imperative that these data are made available for GCs and other clinicians to provide optimal evidence-based care.

Study Limitations

This study reflects the experiences and opinions of 78 GCs who have counseled about mosaic embryos. Given this sample size and possible variability in the levels of experience with mosaic embryos among participants, our findings may not be generalizable to all GCs who provide mosaic embryo counseling. In addition, it is difficult to estimate a response rate for our survey because the true number of GCs who have provided counseling about mosaic embryos is not known. Finally, participants' familiarity with mosaic embryos was assessed using a questionnaire created by the investigators on the basis of current literature and published guidelines and is not yet validated.

CONCLUSION

This is the first study to describe clinical activities performed by GCs and to explore challenges they experienced while counseling about mosaic embryos. Although our results may not be generalizable to all GCs, our findings voice a call for more short- and long-term outcome data on mosaic embryo pregnancies and for evidence-based clinical guidelines. We endorse pretest counseling for all patients considering PGT-A, which should address the possibility of mosaic results, associated risks and outcomes, and prenatal testing options. Service delivery models that embed GCs within fertility clinics to provide pretest PGT-A counseling may help optimize informed PGT-A and MET decision-making among patients. A genetic counseling practice guideline, such as the one published by the American Society for Reproductive Medicine Genetic Counseling Professional Group in 2020 (3), may help GCs and other clinicians provide pretest PGT-A counseling. The fact that a standardized genetic counseling guideline was the most desired resource among the GCs in our study suggests that continual reassessment of available counseling guidelines is needed as new data become available. Differing recommendations for the prenatal testing of mosaic embryo pregnancies among GCs in the study warrant further investigation into contributing factors. Finally, further study into which patients are referred for genetic counseling by fertility clinics is warranted to assess gaps in the provision of genetic counseling for mosaic embryos.

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