

ORIGINAL ARTICLE

Effects of chromosome 9 inversion on IVF/ICSI: A 7-year retrospective cohort study

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Abstract

Background: This study focused on the outcomes of patients with pericentric inversion of chromosome 9 who underwent IVF/ICSI and fresh day 2 or day 3 embryo transfer and the possible impacts of carrier gender and chromosome karyotype on pregnancy outcomes.

Methods: A total of 214 couples (107 couples with one pericentric inversion of chromosome 9 in one partner [Group 1], 107 couples with normal karyotypes [Group 2]) underwent their first IVF/ICSI treatment and were included in this study. Oocyte number, normal fertilization rates, abnormal fertilization rates, cleavage rates, embryo utilization rates, fresh embryo transfer rates, clinical pregnancy rates (CPR), implantation rates, miscarriage rates, and live birth rates per embryo transfer (LBR) were compared between groups.

Results: Group 1 did not show any disadvantage when compared with Group 2. The CPR and LBR were similar between all groups. The female carrier group had a higher normal fertilization rate and higher utilization rate than the male carrier group. Cases with inv(9)(p12;q13) had a lower utilization rate but a higher implantation rate than the remaining karyotypes.

Conclusion: In the first IVF or ICSI cycle, couples with one pericentric inversion of chromosome 9 in one partner had satisfactory outcomes. The subgroup analysis showed a tendency of better prognosis for the female carrier and inv(9)(p12;q13) type.

KEYWORDS

gender, IVF/ICSI outcomes, karyotype, pericentric inversion of chromosome 9

1 | INTRODUCTION

Since the discovery of the 46 chromosomes in human cells in 1956 (Smeets, 2004), cytogenetics has helped clinicians investigate the etiology of congenital abnormalities and diseases, including infertility (Sahin et al., 2008) and spontaneous abortion (Sheth et al., 2013). With the development of chromosome banding techniques, karyotyping

provides more information on the structure of chromosomes. Among the various chromosome changes identified, the impacts of pericentric inversion on human chromosome 9 are controversial. Several studies have claimed it was a normal variation because the frequency showed no difference between the general population and infertile couples (Dana & Stoian, 2012; Hong, Zhou, Tao, Wang, & Zhao, 2011). However, others demonstrated a possible

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relationship of inversion on chromosome 9 to hematologic disorders (Suh, Song, Kim, Park, & Choi, 2010), infertility (Minocherhomji et al., 2009; Mozdarani, Meybodi, & Karimi, 2007; Muthuvel, Ravindran, Chander, & Subbian, 2016), and poor outcomes of assisted reproduction treatment (Liang et al., 2014). Whether and how inversion on chromosome 9 affects the outcome of IVF or ICSI remains unclear.

In China, patients who intend to have IVF or ICSI treatment need to undergo karyotyping first. Therefore, we identified many cases with chromosome polymorphisms. Inversion on chromosome 9 is the most common. The frequency of each kind of chromosome change is low. Thus, previous studies usually classified different chromosomal changes into one group for comparison with a control group. It is difficult to determine the outcome until live birth. This study focused on outcomes of inversion on chromosome 9 patients who underwent IVF or ICSI and fresh day 2 or day 3 embryo transfer in a 7-year time period. In addition, the possible impacts of the carrier gender and karyotypes were investigated.

2 | METHODS

2.1 | Ethical compliance

This study was approved on 11 March 2016, by the Ethics Committee of Shanghai First Maternity and Infant Hospital (approval no. KS1546).

2.2 | Study design and experimental subjects

This retrospective cohort study was conducted in infertile couples. A total of 6,578 couples underwent their first IVF or ICSI cycle in the Centre for Reproductive Medicine from 1 July 2010, to 8 December 2017. The history, examination results, embryological data, and pregnancy outcomes were analyzed. Every couple was assigned a unique sequence record number when they decided to undergo IVF/ICSI treatment. Donor cycles were excluded from this study. The inversion on chromosome 9 cases in this study was not grouped together with 9qh+ or other kinds of chromosomal polymorphisms and abnormalities.

There were 107 couples with one inversion on chromosome 9 in one partner. They were designated as Group 1. A total of 107 cases were randomly selected from the normal karyotype cases by SPSS22 (all cases were identified by the record number) and were designated as Group 2. Groups 1 and 2 were further divided into subgroups:

Subgroup 1ivf included 85 couples who underwent IVF from Group 1;

Subgroup 2ivf included 74 couples who underwent IVF from Group 2;

Subgroup 1icsi included 22 couples who underwent ICSI from Group 1;

Subgroup 2icsi included 33 couples who underwent ICSI from Group 2.

Subgroup 1a included 53 couples with a female carrier;

Subgroup 1b included 54 couples with a male carrier;

Subgroup 1c included 86 couples with inv(9)(p12;q13);

Subgroup 1d included 21 couples with the remaining inversion karyotype, non inv(9)(p12;q13).

2.3 | Karyotyping

Peripheral blood lymphocytes were cultured at 37°C for 68 hr in lymphocyte culture medium and then treated with 20 µg/ml colchicine for 4 hr. The lymphocytes were harvested and subjected to hypotonic treatment, fixation, trypsinization, and Giemsa banding (500–550 band level). For each patient, not less than 20 metaphase cells were analyzed. Karyotype and chromosome polymorphisms were reported according to the International System for Human Cytogenetic Nomenclature. The peripheral karyotypes were assumed to be reflective of the respective partner's gametes.

2.4 | Ovarian stimulation and IVF or ICSI

The ovarian stimulation protocol has been described elsewhere (Yang et al., 2015). The exact protocol and the dosage of gonadotrophin depended on the female partner's age, basal follicle stimulating hormone (FSH), antral follicle count, and body mass index (BMI). The development of follicles was monitored by ultrasound examination and serum E₂ concentration. Oocyte retrieval occurred 36–40 hr after human chorionic gonadotrophin (HCG) trigger. Men with more than 5 million forward progressive sperm underwent IVF; otherwise, they underwent ICSI. All good quality embryos were frozen when the patients had a serum progesterone level higher than 1.5 ng/ml on human chorionic gonadotrophin day, a high risk of OHSS, an endometrial thickness of less than 7 mm on embryo transfer day, or GnRH-a triggered cycles. Otherwise, fresh embryo transfer was offered.

Good quality embryos were transferred on day 2 or day 3. Before April 2013, not more than two embryos were transferred to young women (under 35) in the first cycle. Not more than three embryos were transferred for women older than 35 or with previous failure. After April 2013, not more than two embryos were transferred for all patients. Patients with uterus malformation or previous Cesarean section were encouraged to replace one embryo.

2.5 | Outcomes

To explore whether inversion on chromosome 9 affects IVF or ICSI outcomes, the following factors were analyzed and compared among the study groups: female age, male age, female BMI, basal FSH, ovarian stimulation protocol (super long, long, short, natural, soft, antagonist, or others), insemination method (IVF or ICSI), oocyte number, normal and abnormal fertilization rates, cleavage rates, embryo utilization rates, fresh embryo transfer rates, clinical pregnancy rates (CPR), implantation rates, miscarriage rates, and live birth rates per embryo transfer (LBR).

The normal fertilization rate referred to the proportion of the zygotes with two pronuclei on day 1 among all the inseminated oocytes. The abnormal fertilization rate referred to the proportion of the zygotes with more than two pronuclei and one pronucleus from ICSI among all the fertilized oocytes. The cleavage rate referred to the proportion of fertilized oocytes that cleaved to form embryos. The utilization embryo rate referred to the proportion of embryos with sufficient quality for transfer or cryopreservation among all embryos. The evaluation criteria are shown below.

The CPR referred to the proportion of cycles with patients having a gestational sac(s) seen by ultrasound 4 weeks after embryo transfer. The implantation rate was the quotient of the number of sacs detected by ultrasound at gestational week 6 to the number of embryos transferred. The miscarriage rate was the quotient of the number of pregnancy losses before gestational week 28 by the number of clinical pregnancies. A live birth was defined as any birth event in which at least one baby was born alive. The LBR per embryo transfer refers to the proportion of live birth cycles among all the fresh embryo transfer cycles.

2.6 | Embryo evaluation criterion

Fertilization was checked at 17 ± 1 hr after insemination (day 1). The number of pronuclei was determined. Each zygote was individually cultured in a droplet of medium. Embryo morphology was assessed 44 ± 1 hr after insemination (day 2) and 68 ± 1 hr after insemination (day 3). The embryos were classified into the following six categories:

- I: even blastomeres, fragments less than 5%
- II: even blastomeres, fragments between 5% and 25%
- III: uneven blastomeres, fragments less than 5%
- IV: uneven blastomeres, fragments between 5% and 25%
- V: countable blastomeres, fragments more than 25%
- VI: not able to distinguish blastomeres or fragments

Embryos belonging to categories I–IV were considered usable for embryo transfer or cryopreservation.

2.7 | Statistical analysis

Statistical analyses were performed with SPSS 22 software (IBM, Armonk, NY, USA). A difference with a two-sided $p < .05$ was considered statistically significant. Data are expressed as the mean \pm S.E.M. Where appropriate, Student's *t* test or the nonparametric test (the Mann–Whitney *U* test) was used to analyze numerical data, while Pearson's chi-squared test or Fisher's exact test was used to analyze categorical data. The binary logistic regression model was used to analyze odds ratios.

3 | RESULTS

3.1 | Pericentric inversion on chromosome 9 prevalence and subtypes

The prevalence of pericentric inversion on chromosome 9 in this study was 1.63% (107/6578), and the incidences were different in several population groups (Hsu et al., 1987). The frequency distribution of all kinds of karyotypes in males and females is shown in Table 1. A total of 49.53% of the couples were female carriers, while 50.47% were male carriers. Inv(9)(p12;q13) was the most common type (80.37%, 86/107) found in this study.

3.2 | Baseline comparison

The demographic data of all the groups are shown in Tables 2–6. Group 1 had more primary infertility cases and lower FSH levels than Group 2, and in Group 1ivf than Group 2ivf. Female BMI was higher in Group 1icsi than that in Group 2icsi. The IVF/ICSI ratio and ovarian stimulation protocol showed no difference between the groups.

TABLE 1 Frequency distribution of pericentric chromosome 9 inversion

Karyotype of females	Cases	Karyotype of males	Cases	Sum
46,XX,inv(9)(p12;q13)	45	46,XY,inv(9)(p12;q13)	41	86
46,XX,inv(9)(p12;q22)	2	46,XY,inv(9)(p12;q22)	1	3
46,XX,inv(9)(p13;q13)	2	46,XY,inv(9)(p13;q13)	6	8
46,XX,inv(9)(p13;q22)	4	46,XY,inv(9)(p13;q22)	5	9
		46,XY,inv(9)(p22;q22)	1	1
Total	53		54	107

TABLE 2 Characteristics and outcomes of pericentric inversion chromosome 9 group and control group

	Group 1 (n = 107)	Group 2 (n = 107)	p
Female age (years)	33.00	32.00	.526
Male age (years)	33.00	34.00	.000*
Female BMI	21.90	21.60	.733
Basic FSH (IU/L)	7.33	7.93	.001*
Primary/secondary infertility	73/34	53/54	.005* OR 2.188 95% CI [1.254, 3.815]
IVF/ICSI	85/22	74/33	.085
Protocol			.433
Oocyte	13.00	14.00	.056
Total oocyte	1,128	1,041	
Normal Fertilization rate (%)	753/1128 (66.76%)	663/1041 (63.69%)	.134
Abnormal Fertilization rate (%)	87/840 (10.36%)	72/735 (9.8%)	.712
Cleavage rate (%)	800/840 (95.24%)	670/735 (91.16%)	.001* OR 1.940 95% CI [1.292, 2.915]
Utilization rate (%)	509/800 (63.63%)	394/670 (58.81%)	.059
Total number of embryo transferred	144	144	
Patients with transfer (%)	75/107 (70.09%)	76/107 (71.03%)	.881
Clinical pregnancy rate (%)	32/75 (42.67%)	32/76 (42.11%)	.944
Implantation rate (%)	44/144 (30.56%)	43/144 (29.86%)	.898
Live birth rate per embryo transfer (%)	29/75 (38.67%)	28/76 (36.84%)	.817
Miscarriage rate (%)	3/32 (9.38%)	4/32 (12.50%)	.688 ^a

Note: Group 1 = pericentric inversion chromosome 9 group, Group 2 = control group.

Abbreviations: BMI, body mass index; FSH, follicle stimulating hormone.

^aFisher's exact test was used.

* $p < .05$, the difference was considered statistically significant.

3.3 | Embryological indexes

Most indexes were similar between pericentric inversion on chromosome 9 and control, regardless of IVF, ICSI, or IVF/ICSI. The cleavage rate was higher in Group 1 than in Group 2, and in Group 1ivf than in Group 2ivf.

TABLE 3 Characteristics and outcomes of pericentric inversion chromosome 9 patients with IVF and control with IVF

	Group 1ivf (n = 85)	Group 2ivf (n = 74)	p
Female age (years)	33.00	32.00	.000*
Male age (years)	33.00	34.00	.000*
Female BMI	21.80	21.92	.051
Basic FSH (IU/L)	7.33	7.93	.024*
Primary/secondary infertility	59/26	31/43	.000*
Protocol			.418
Oocyte	13.00	13.00	.778
Total oocyte	926	720	
Normal Fertilization rate (%)	631/926 (68.14%)	483/720 (67.08%)	.649
Abnormal Fertilization rate (%)	80/711 (11.25%)	56/539 (10.39%)	.628
Cleavage rate (%)	676/711 (95.08%)	492/539 (91.28%)	.007* OR 1.845 CI [1.173, 2.902]
Utilization rate (%)	432/676 (63.91%)	294/492 (59.76%)	.149
total number of embryo transferred	105	109	
Patients with transfer (%)	55/85 (64.71%)	58/74 (78.38%)	.058
Clinical pregnancy rate (%)	21/55 (38.18%)	23/58 (39.66%)	.872
Implantation rate (%)	30/105 (28.57%)	31/109 (28.44%)	.983
Live birth rate per embryo transfer (%)	17/55 (30.91%)	21/58 (36.21%)	.551
Miscarriage rate (%)	4/21 (19.05%)	2/23 (8.70%)	.315 ^a

Note: Group 1ivf = patients underwent IVF from Group 1, Group 2ivf = patients underwent IVF from Group 2.

Abbreviations: BMI, body mass index; FSH, follicle stimulating hormone.

^aFisher's exact test was used.

* $p < .05$, the difference was considered statistically significant.

Female carriers may have better embryos than male carriers. The normal fertilization rate and the utilization rate were significantly higher in Group 1a than in Group 1b (71.30% vs. 62.37%, OR 1.499 95% CI [1.168, 1.924]; 68.74% vs. 58.01%, OR 1.592 95% CI [1.191, 2.127]).

The abnormal fertilization rate was significantly higher in Group 1d than that in Group 1c (16.06% vs. 8.66%, OR 0.495 95% CI [0.309, 0.794]). The utilization rate was significantly

TABLE 4 Characteristics and outcomes of pericentric inversion chromosome 9 patients with ICSI and control with ICSI

	Group 1icsi (n = 22)	Group 2icsi (n = 33)	p
Female age (years)	32.00	34.00	.000*
Male age (years)	34.00	35.00	.001*
Female BMI	22.00	21.20	.003*
Basic FSH (IU/L)	7.30	7.56	.004*
Primary/secondary infertility	14/8	22/11	.780
Protocol			.773
Oocyte	14	14	.009*
Total oocyte	202	321	
MII oocyte	161/202 (79.70%)	263/321 (81.93%)	.526
Normal Fertilization rate (%)	122/161 (75.78%)	180/263 (68.44%)	.105
Abnormal Fertilization rate (%)	7/129 (5.43%)	16/196 (8.16%)	.347
Cleavage rate (%)	124/129 (96.12%)	178/196 (89.89%)	.068
Utilization rate (%)	77/124 (62.10%)	100/178 (56.18%)	.304
Total number of embryo transferred	39	35	
Patients with transfer (%)	20/22 (90.91%)	18/33 (54.55%)	.004* OR 8.333 CI [1.671, 41.563]
Clinical pregnancy rate (%)	11/20 (55%)	9/18 (50%)	.758 ^a
Implantation rate (%)	14/39 (35.90%)	12/35 (34.29%)	.885
Live birth rate per embryo transfer (%)	11/20 (55%)	7/18 (38.89%)	.319 ^a
Miscarriage rate (%)	0/11 (0%)	2/9 (22.22%)	.063 ^a

Note: Group 1icsi = patients underwent ICSI from Group 1, Group 2icsi = patients underwent ICSI from Group 2.

Abbreviations: BMI, body mass index; FSH, follicle stimulating hormone.

^aFisher's exact test was used.

* $p < .05$, the difference was considered statistically significant.

higher in Group 1d than that in Group 1c (83.70% vs. 57.63%, OR 0.265 95% CI [0.174, 0.404]).

3.4 | Clinical pregnancy and live birth

No statistical significance was found in the CPR between groups. It was similar between Group 1 and Group 2 (42.67%

TABLE 5 Characteristics and outcomes of female carriers and male carriers

	Group 1a (n = 53)	Group 1b (n = 54)	p
Female age (years)	31.53 ± 4.432	32.37 ± 4.435	.609
Male age (years)	32.00	32.00	.925
Female BMI	21.80 ± 2.54	21.98 ± 2.63	.717
Basic FSH (IU/L)	6.52 ± 1.86	7.32 ± 3.60	.172
Primary/secondary infertility	37/16	36/18	.728
IVF/ICSI	42/11	43/11	.961
Protocol			.121
Oocyte	10.45 ± 5.51	10.63 ± 5.49	.757
Total oocyte	554	574	
Normal Fertilization rate (%)	395/554 (71.30%)	358/574 (62.37%)	.001 ^b OR 1.499 95% CI [1.168, 1.924]
Abnormal Fertilization rate (%)	45/440 (10.23%)	42/400 (10.50%)	.897
Cleavage rate (%)	419/440 (95.23%)	381/400 (95.25%)	.988
Utilization rate (%)	288/419 (68.74%)	221/381 (58.01%)	.002* OR 1.592 95% CI [1.191, 2.127]
Total number of embryo transferred	71	73	
Patients with transfer (%)	38/53 (71.70%)	37/54 (68.52%)	.719
Clinical pregnancy rate (%)	19/38 (50%)	13/37 (35.14%)	.193
Implantation rate (%)	26/71 (36.62%)	18/73 (24.66%)	.119
Live birth rate per embryo transfer (%)	18/38 (47.37%)	10/37 (27.03%)	.069
Miscarriage rate (%)	1/19 (5.26%)	3/13 (23.08%)	.135 ^a

Note: Group 1a = female carriers, Group 1b = male carriers.

Abbreviations: BMI, body mass index; FSH, follicle stimulating hormone.

^aFisher's exact test was used.

* $p < .05$, the difference was considered statistically significant.

vs. 42.11%) was also similar in Group 1a and Group 1b (50% vs. 35.14%). The difference did not reach statistical significance, probably due to the small number of clinical pregnancies in Group 1c and Group 1d (47.46% vs. 25%).

TABLE 6 Characteristics and outcomes of inv(9)(p12;q13) patients group and non-inv(9)(p12;q13) group

	Group 1c (n = 86)	Group 1d (n = 21)	p
Female age (years)	32.14 ± 4.36	31.19 ± 4.76	.382
Male age (years)	33.00	31.00	.122
Female BMI	21.92 ± 2.61	21.76 ± 2.49	.804
Basic FSH (IU/L)	7.00	6.98	.544
Primary/secondary infertility	59/27	14/7	.865
IVF/ICSI	69/17	16/5	.683
Protocol			.808
Oocyte	9.50	11.00	.273
Total oocyte	879	890	
Normal Fertilization rate (%)	591/879 (67.24%)	162/249 (65.06%)	.520
Abnormal Fertilization rate (%)	56/647 (8.66%)	31/193 (16.06%)	.003* OR 0.495 95% CI [0.309, 0.794]
Cleavage rate (%)	616/647 (95.21%)	184/193 (95.34%)	.942
Utilization rate (%)	355/616 (57.63%)	154/184 (83.70%)	.000* OR 0.265 95% CI [0.174, 0.404]
Total number of embryo transferred	111	33	
Patients with transfer (%)	59/86 (67.44%)	16/21 (76.19%)	.496
Clinical pregnancy rate (%)	28/59 (47.46%)	4/16 (25%)	.107
Implantation rate (%)	39/111 (35.14%)	5/33 (15.15%)	.029* OR 3.033 95% CI [1.085, 8.482]
Live birth rate per embryo transfer (%)	24/59 (40.68%)	4/16 (25%)	.086 ^a
Miscarriage rate (%)	4/28 (14.29%)	0/4 (0%)	.284 ^a

Note: Group 1c = inv(9)(p12;q13) patients group, Group 1d = the remaining types–non-inv(9)(p12;q13) group.

Abbreviations: BMI, body mass index; FSH, follicle stimulating hormone.

^aFisher's exact test was used.

*p < .05, the difference was considered statistically significant.

Interestingly, the implantation rate was significantly higher in Group 1c than in Group 1d (35.14% vs. 15.15%, OR 3.033 95% CI [1.085, 8.482]). There was no statistical significance in implantation rates between other groups.

The LBRs were similar between all groups. While LBR was higher in the female carrier group than in the male carrier group, the difference was not statistically significant.

4 | DISCUSSION

The average oocyte number, normal fertilization rate, proportion of patients with fresh embryo transfer, CPR, and miscarriage rate were similar between the pericentric inversion on chromosome 9 group and control group. These results are consistent with an earlier study showing no adverse impact of chromosome polymorphic variations on the implantation rate and the CPR (Hong et al., 2011). The cleavage rate was higher in the pericentric inversion on chromosome 9 group than that of the control group. This may be related to more primary infertility cases in the pericentric inversion on chromosome 9 group.

The outcomes were statistically similar between the female carrier group and the male carrier group. A better prognosis may occur in female carriers than male carriers. Similar situations were found in previous studies. One published in 2011 showed that there was a trend toward higher first trimester pregnancy loss rates in the male chromosomal polymorphic variations group, but not in the female chromosomal polymorphic variations group (Hong et al., 2011). In another study, chromosome polymorphisms in male carriers affected outcomes by decreasing fertilization rate, cleavage rate, good quality embryos, ongoing pregnancy rate, and LBR but only affected the cleavage rate in female carriers (Samonte, Conte, Ramesh, & Verma, 1996). In 2017, couples with chromosomal polymorphisms in male partners have poor pregnancy outcomes after IVF treatment manifesting as high cumulative miscarriage rate and low LBR after a complete cycle (Ni et al., 2017).

Seven types of rearrangements have been reported for pericentric inversion on chromosome 9 (Samonte et al., 1996), and five types of pericentric inversion were found in this study with limited sample size. Earlier studies showing constitutional inversions affecting the pericentromeric region of chromosome 9 carry breakpoints located diversely and preferentially in 9p12 or 9q13-21.1 and less frequently in 9q12 (Demirhan, Pazarbasi, Suleymanova-Karahan, Tanriverdi, & Kilinc, 2008; Starke et al., 2002).

Several genes located in 9q22 might be related to embryo quality. Spindlin1 (HGNC approved symbol *SPINI*, OMIM *609,936, genomic coordinates (GRCh38): 9:88,388,381-88,478,707) (Gao et al., 2005) plays an important role in gametogenesis and cell cycle regulation during the transition from gamete to embryo. Cell division cycle 14B (HGNC approved symbol *CDC14B*, OMIM * 603,505,

Genomic coordinates (GRCh38): 9:96,492,742-96,619,829) (Wei et al., 2011) is required for efficient DNA damage repair in human cells. Growth arrest and DNA damage inducible gamma (HGNC approved symbol *GADD45G*, OMIM * 604949, Genomic coordinates (GRCh38): 9:89,605,008-89,606,554) (Kaufmann, Gierl, & Niehrs, 2011) is involved in diverse processes, including cell cycle, apoptosis, DNA repair, and DNA demethylation.

Furthermore, genes located in 9p13 might be related to embryo implantation potential and/or endometrial receptivity. Talin1 (HGNC approved symbol *TLN1*, OMIM * 186745, Genomic coordinates (GRCh38): 9:35,697,336-35,732,394) (Monkley et al., 2011) produces an angiogenesis phenotype that is restricted to newly forming blood vessels throughout the embryo development stage. Maternal embryonic leucine zipper kinase (HGNC approved symbol *MELK*, OMIM * 607025, Genomic coordinates (GRCh38): 9:36,572,861-36,677,682) (Heyer, Warsowe, Solter, Knowles, & Ackerman, 1997) may play a role in the signal transduction events in the egg and early embryo.

Routine embryo selection during IVF or ICSI may improve reproductive outcomes by excluding zygotes with poly pronuclei or embryos with severe fragmentation or embryos developing too fast or too slow. It would be interesting to culture these embryos to the blastocyst stage, perhaps with the help of a time-lapse video-microscopy system. Preimplantation genetic testing may provide more information if any duplication or deletion were detected.

According to Online Mendelian Inheritance in Man (OMIM), several genetic disorders are related to genes located on chromosome 9, including cerebral palsy (OMIM #605388) (Lerer et al., 2005), ataxia (OMIM #208920) (Chamberlain et al., 1988), deafness (OMIM #600974) (Hilgert et al., 2008), cataract (OMIM #613887) (Héon et al., 2001), and melanoma (OMIM #155755) (Cannon-Albright et al., 1992). In the present study, none of these disorders were found in any of the studied subjects or their infants. Some of these are autosomal recessive disorders, and the exact genotypes of our studied subjects need to be determined before a definitive conclusion can be drawn.

In this study, we failed to collect the karyotype information of the resulting babies. The cumulative LBR was not analyzed.

In summary, in the first IVF or ICSI cycle, couples with one pericentric inversion on chromosome 9 carrier had satisfactory outcomes. The subgroup analysis showed a tendency of better prognosis for the female carrier group, but this needs to be confirmed by a larger study. Patients with inv(9) (p12;q13) may have less abnormal fertilized embryos and a higher implantation rate than other types. This information is helpful for clinical genetic counseling. Whether there are any changes in gene function in pericentric inversion on chromosome 9 needs to be explored.

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CONFLICT OF INTERESTS

The author(s) declared no potential conflict of interest with respect to the research, authorship, and/or publication of this article.

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