



RESEARCH ARTICLE

Cytogenetic analysis of 2959 couples with spontaneous abortion and detailed analysis of rare karyotypes

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Abstract. Chromosome abnormality is one of the important causes of spontaneous abortion. However, due to regional and ethnic differences, the reported rates of chromosomal abnormalities in patients with spontaneous abortion vary greatly. At present, there is no large sample statistics of chromosome abnormality in patients with spontaneous abortion in Yantai, Shandong province, China and hence 2959 couples (5918 individuals) with spontaneous abortion were recruited for this study. G banding was used to examine the karyotype of patients. The results showed that chromosomal abnormalities were present in 173 of 2959 couples with the rate of 5.85%. Female carriers were significantly higher than male. Chromosomal abnormality rate was positively correlated with the number of spontaneous abortions. Structural aberrations were significantly greater than numerical aberrations, with a prevalence of 92.49% and 7.51%, respectively. Balanced translocation, Robertson translocation and inversion were the most common types of chromosomal structural abnormalities. Among them, the proportion of balanced translocation was the highest (63.13%, 101/160). In addition, three cases of rare complex abnormal karyotype were detected. In summary, chromosome abnormality could be one of the important causes of spontaneous abortion in Yantai, Shandong province, China. The sex of patients with chromosomal abnormalities and the number of spontaneous abortions should be considered in genetic counselling. When one of the partners have chromosome abnormality, preimplantation genetic diagnosis and prenatal diagnosis could play a great significance for preventing the birth of children with chromosomal diseases and reducing birth defects.

Keywords. chromosomal abnormality; spontaneous abortion; rare karyotype; balanced reciprocal translocations; genetic counselling.

Introduction

Abortion that occurs in a natural state (not for human purposes) is called spontaneous abortion. Spontaneous abortion occurs in ~15–20% of all clinically recognizable pregnancies (Rai and Regan 2006; Stephenson and Kutteh 2007). Spontaneous abortion is divided into early abortion (<12 weeks) and late abortion (12–28 w). In almost 50% of the cases, the aetiology is unknown. The common causes of abortion include: chromosomal abnormalities, maternal endocrine disorders (e.g., luteal insufficiency, polycystic ovary syndrome, hyperprolactinaemia, thyroid and diabetes), abnormalities of maternal reproductive tract (e.g., uterine deformity, Asherman syndrome, cervical insufficiency, uterine fibroids and genital tract infection), and an unhealthy lifestyle (e.g., smoking, alcohol abuse, excessive consump-

tion of caffeine and environmental factors such as organic solvents and toxins).

Chromosome abnormality is one of the important causes of spontaneous abortion. Research shows that in the foetuses of spontaneous abortion, chromosomal abnormality is found to be 50–70% (Carp *et al.* 2004), among which triploidy is 18%. Triploid foetuses are prone to abortion because of the formation of tertiary spindles in the process of embryo development during mitosis, resulting in the distribution disorder of chromosomes in the middle and late stage of cell division, which seriously interferes with the normal development of embryos and leads to abortion. The frequency of chromosomal abnormalities among couples with spontaneous abortion varies from 2 to 10% (Dutta *et al.* 2011; Ayed *et al.* 2017; Yildirim *et al.* 2019; Pal *et al.* 2018; Fan *et al.* 2016), much higher than the 0.5% of the normal population (Fryns *et al.* 1984; Yang *et al.* 2014). The presence of chromosomal rearrangements can result in abnormal distribution of chromosomes during meiosis, which leads to the

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imbalance of gamete chromosomes. Gamete chromosomes imbalance will seriously affect the normal development of embryos, resulting in spontaneous abortion.

Chromosomal karyotype analysis has become one of the important methods to find the cause of abortion. However, due to regional and ethnic differences, the reported rates of chromosomal abnormalities in patients with spontaneous abortion vary greatly. At present, there is no large sample statistics of chromosome abnormality in patients with spontaneous abortion in Yantai. For this purpose, we collected 2959 couples with a history of spontaneous abortion in Yantai, tested their peripheral blood chromosomes, and conducted statistical analysis on the incidence and distribution of abnormal chromosomes. Our study will further clarify the role of chromosomal abnormalities in spontaneous abortion and provide references for genetic counselling of patients with spontaneous abortion. In addition, three rare complex karyotypes are described in detail.

Materials and methods

Patients

A total of 2959 couples (5918 individuals) with spontaneous abortion in the Yantai Yu Huang Ding Hospital from 1 January 2013 to 31 December 2018 were recruited. The age group of the subjects ranged from 22 years to 49 years. The clinical data of confirmed cases were retrospectively collected and analysed. Miscarriages due to immune effects, uterine abnormalities and other causes were excluded. The study was approved by the Ethical Committee of Yantai Yu Huang Ding Hospital. Informed consent was obtained from all participants.

G banding

Heparin anticoagulant blood, 0.8 mL was added to 5 mL lymphocyte culture medium and cultured in 37°C. After 68–72 h of incubation, colchicine (1 mg/mL) was added and incubated for another 2 h. Then the cells were treated with hypotonic solution of 0.075 M KCl at 37°C for 35 min, and fixed thrice using fixation liquid (methanol and acetic acid in a ratio of 3:1). Karyotype analysis was performed on G-banded metaphase chromosomes using a standard protocol that generated 400–450 band resolutions. Thirty metaphases per patient were counted, and a minimum of five metaphases were analysed. For mosaicism, at least 100 metaphases were counted. Chromosome polymorphisms, such as pericentric inversion 9 variant, centromeric heterochromatin variants and satellite variants were described in detail and classified as normal. Karyotype reports were based on the International System for Human Cytogenetic Nomenclature (ISCN 2013).

Statistical analysis

All data were analysed using SPSS v.17.0 for Windows (SPSS, Chicago, USA). Parametric variables were compared using the linear-by-linear association. $P < 0.05$ was considered to be statistically significant.

Results

A total of 2959 couples (5918 cases) with spontaneous abortion were examined. The median age of male was 31.45 years \pm 5.63 and the median age of female was 30.81 \pm 5.08. The number of spontaneous abortion varied from one to eight abortions/couple. Among them, the

Table 1. The relationship between chromosomal abnormalities and number of miscarriages.

	Number of spontaneous abortion					Total
	1	2	3	4	≥ 5	
Number of couples	775	1927	207	39	11	2959
Chromosomal abnormalities	49	81	34	5	4	173
Abnormalities (%)	6.32	4.11	16.43	12.82	3.64	5.85

Table 2. Distribution of abnormal karyotypes.

Gender	Reciprocal translocation	Robertsonian translocation	Inversion	Aneuploidy/mosaic aneuploidy	fra(16)	Deletion	Marker	Total
Male	36	10	13	1	3	0	0	63
Female	65	21	10	11	1	1	1	110
Total	101	31	23	12	4	1	1	173

Table 3. Distribution of karyotypes with reciprocal translocations.

	Karyotype		Karyotype
1	46,XX,t(1;2)(p22.3;q35)	51	46,XY,t(6;9)(p21;q24.2)
2	46,XX,t(1;17)(p13.1;q21.3)	52	46,XX,t(6;7)(q25.1;p15)
3	46,XX,t(1;20)(p36.1;q11.2)	53	46,XX,t(6;8)(q15;q11.23)
4	46,XX,t(1;21)(p22.3;q22.3)	54	46,XX,t(7;9)(p15.3;p22)
5	46,XX,t(1;3)(p34.1;q21)	55	46,XX,t(7;12)(p13;q21.2),inv(9)(p11q12)
6	46,XX,t(1;4)(p34;q28)	56	46,XX,t(7;13)(p12;q22)
7	46,XX,t(1;4)(q41;q15.2)	57	46,XY,inv(4)(q31.1q35),t(8;18)(q13;q12.2)
8	46,XY,t(1;22)(p21;q13)	58	46,XY,t(8;15)(q23;q26.1)
9	46,XY,t(1;6)(q25;q27)	59	46,XX,t(8;14)(q24;q31)
10	46,XY,t(1;7)(p36.1;q22)	60	46,XY,t(7;10)(p22;q22)
11	46,XX,t(1;5)(p33;p15.3)	61	46,XY,t(7;11)(q32;q21)
12	46,XX,t(1;6)(q32.1;q22.2)	62	46,XY,t(7;16)(q21.2;p13.1)
13	46,XX,t(2;11)(q37;q23)	63	46,XY,t(7;9)(p10;q10)
14	46,XX,t(2;12)(q37;q24)	64	46,XX,t(8;18)(p23;q21.3)
15	46,XX,t(2;16)(p25.1;q13)	65	46,XY,t(9;10)(p23;q24.3)
16	46,XX,t(2;18)(q23;q21.1)	66	46,XY,t(9;12)(p22;q15)
17	46,XX,t(2;3)(q11.2;q23)	67	46,XY,t(9;16)(p22;q12.2)
18	46,XX,t(2;3)(q21.3;q25)	68	46,XX,t(9;18)(p24;q21.1)
19	46,XX,t(2;3)(q37;p21.1)	69	46,XX,t(9;22)(q21.3;q11.2)
20	46,XX,t(2;3)(q37;p21.2)	70	46,XX,t(10;11)(q26;q13)
21	46,XY,t(2;20)(p23;q13.3)	71	46,XX,t(10;12)(p11.2;p11.2)
22	46,XY,t(2;3)(q37;p12)	72	46,XY,t(10;12)(q24;q13)
23	46,XY,t(2;8)(q25;p11.2)	73	46,XY,t(10;17)(p15;q22)
24	46,XX,t(2;6)(q35;q25.3)	74	46,XY,t(10;20)(q26.3;q11.2)
25	46,XX,t(3;13)(q29;q23)	75	46,XY,inv(10)(q11.23q23.2),t(10;14)(p11.23;q22)
26	46,XX,t(3;15)(q26.2;q24.1)	76	46,XX,t(10;14)(p11.2;q24)
27	46,XX,t(3;20)(p23;q13.1)	77	46,XX,t(10;20)(p26;q11.2)
28	46,XX,t(3;5)(q23.1;q33.1)	78	46,XY,t(11;12)(q23.3;q22)
29	46,XX,t(3;6)(q13.2;q15)	79	46,XY,t(11;20)(q13.4;p11.2)
30	46,XX,t(3;7)(q12;p22)	80	46,XY,t(11;22)(q23.3;q11.2)
31	46,XY,t(3;14)(p25;q24.3)	81	45,XX,der(11)t(11;13)(q25;p12),-13
32	46,XY,t(3;4)(q13.2;q31.3)	82	46,XX,t(11;12)(q23.3;q11.2)
33	46,XY,t(3;6)(p23;q16.2)	83	46,XX,t(11;13)(q21;q14.1)
34	46,XY,t(3;9)(q15.2;p22)	84	46,XY,t(11;22)(q23.3;q11.2)
35	46,XX,t(3;8)(p21;q21)	85	46,XX,t(11;22)(q23;q11.2)
36	46,XX,t(3;8)(p23;q13),inv(9)(p11q13)	86	46,XX,t(11;22)(q23.3;q11.2)
37	46,XX,t(4;17)(p14;p13)	87	46,XX,t(5;15)(q21;q26)
38	46,XX,t(4;6)(p15.2;p21.1)	88	46,XX,t(5;13)(q33.1;q21.2)
39	46,XY,t(4;13)(p15.2;q32)	89	46,XY,t(5;20)(q33.3;q13.1)
40	46,XY,t(4;15)(p14;q24)	90	46,XX,t(5;16)(q33;q11)
41	46,XY,t(4;21)(p13;q11.1)	91	46,XX,t(5;7)(p13.3;p15.3)
42	46,XY,t(4;8)(p11;p11.1)	92	46,XX,t(6;11)(p11.1;p11.1)
43	46,XX,t(4;6)(p15.2;p21.1)	93	46,XX,t(6;12)(q27;q24.1)
44	46,XX,t(6;14)(q23.3;q13)	94	46,XX,t(12;15)(q15;q32)
45	46,XX,t(6;13)(p23;q22)	95	46,XY,t(12;17)(q15;q25)
46	46,XX,t(6;17)(q27;p11.1)	96	46,XX,t(12;18)(q24.1;q21.1)
47	46,XX,t(6;18)(q15;p11.1)	97	46,XX,t(13;22)(q14.1;q11.2)
48	46,XX,t(6;19)(q27;q13.3)	98	46,XX,t(13;22)(q14;q13)
49	46,XY,t(6;12)(q22.2;q22.3)	99	46,XY,t(15;17)(q13;p11.2)
50	46,XY,t(6;7)(q13;q34)	100	46,XY,t(15;20)(q24;q13.3)
		101	46,XX,t(17;20)(p13;q11.2)

Complex karyotypes are in bold.

proportion of the patients having two spontaneous abortions was the highest (65.12%), and the patients with more than three spontaneous abortions accounted only 8.69% (table 1).

Chromosomal abnormalities were detected in 173 of 2959 couples with 5.85%. The percentage of female (110/173, 63.58%) carrying chromosomal abnormalities was higher than male (63/173, 36.42%) (table 2). No couple presented

an abnormal karyotype in both partners. Chromosomal abnormality rate was positively correlated with the number of spontaneous abortions ($P < 0.001$).

Hundred and sixty cases showed structural aberrations and 13 cases showed numerical aberrations, with a prevalence of 92.49% and 7.51%, respectively. Balanced translocation, Robertsonian translocation and inversion were

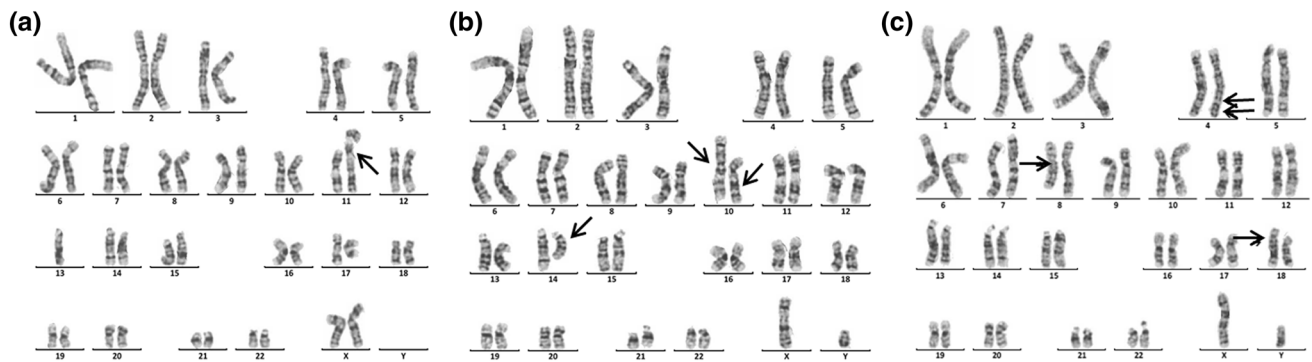


Figure 1. Three cases of rare karyotype. The arrows show abnormal chromosomes. (a) 45,XX,der(11)t(11;13)(q25;p12),-13; (b) 46,XY,inv(10)(q11.23q23.2),t(10;14)(p11.23;q22); (c) 46,XY,inv(4)(q31.1q35),t(8;18)(q13;q12.2).

Table 4. Distribution of karyotypes in Robertsonian translocation.

Karyotype	Total number of cases (%)
45,XY,der(13;14)(q10;q10)	12 (38.71%)
45,XX,der(21;22)(q10;q10)	6 (19.35%)
45,XY,der(15;21)(q10;q10)	3 (9.68%)
45,XX,der(14;21)(q10;q10)	3 (9.68%)
45,XY,der(14;15)(q10;q10)	2 (6.45%)
45XY,der(13;22)(q10;q10)	2 (6.45%)
45,X,Yqh-,der(13;15)(q10;q10)	1 (3.23%)
45,XY,der(13,21)(q10;q10)	1 (3.23%)
45,XX,der(15;22)(q10;q10)	1 (3.23%)
Total	31 (100%)

the most common types of chromosomal structural abnormalities. Chromosome number abnormality was mainly caused by sex chromosome number abnormality (table 2).

Among 101 cases of balanced reciprocal translocations, 19 showed involvement of chromosome 6; and 18 cases showed association of chromosome 3 (table 3). Three rare complex karyotypes were found, 45,XX,der(11)t(11;13)(q25;p12),-13 (figure 1a), 46,XY,inv(10)(q11.23q23.2), t(10;14)(p11.23;q22) (figure 1b), and 46,XY,inv(4)(q31.1q35),t(8;18)(q13;q12.2) (figure 1c).

Robertsonian translocation was found in 31 cases. Among them, chromosomes 13 and 14 were involved in 12 cases (38.71%) (table 4). Inversion was found in 23 cases, mainly involving chromosomes 1, Y, 3 and 11 (table 5; figure 2). In addition, nine cases of X chromosome mosaicism, two cases of 47,XXX, one case of 47,XYY and one case of deletion of Xp were detected, four cases of fra(16) were observed, and one marker chromosome was identified (table 6).

Table 5. Distribution of karyotypes in inversion.

	Karyotype	Total number of cases (%)
inv(1)	46,XX,inv(1)(p13.1q12) (figure 2a)	5 (21.74%)
	46,XX,inv(1)(p22.1p34.1) (figure 2b)	
	46,XX,inv(1)(p11q21) (figure 2c)	
	46,XX,inv(1)(p22q25) (figure 2d)	
	46,XX,inv(1)(q32.1q32.3) (figure 2e)	
inv(10)	46,XY,inv(10)(q11.2q23.2) (figure 2f)	3 (13.04%)
	46,XY,inv(10)(p15q21) (figure 2g)	
	46,XY,inv(10)(q11.23q23.2),t(10;14)(p11.23;q22)(figure 1b)	
inv(Y)	46,X,inv(Y)(p11.2q11.2) (figure 2h)	3 (13.04%)
	46,X,inv(Y)(p11.1q12)	
	46,X,inv(Y)(p11.2q11.23)	
inv(11)	46,XY,inv(11)(q13q21) (figure 2i)	3 (13.04%)
	46,XY,inv(11)(p15.4q21) (figure 2j)	
	46,XY,inv(11)(q13.2q23.2) (figure 2k)	
inv(2)	46,XX,inv(2)(p14p16) (figure 2l)	2 (8.70%)
	46,XY,inv(2)(p11.1q13) (figure 2m)	
inv(4)	46,XY,inv(4)(q31.1q35),t(8;18)(q13;q12.2) (figure 1c)	2 (8.70%)
	46,XX,inv(4)(p12q21) (figure 2n)	
inv(3)	46,XX,inv(3)(p23q11.2) (figure 2o)	1 (4.35%)
inv(5)	46,XY,inv(5)(p15q32) (figure 2p)	1 (4.35%)
inv(12)	46,XX,inv(12)(q13q15) (figure 2q)	1 (4.35%)
inv(13)	46,XY,inv(13)(q14.1q21.2) (figure 2r)	1 (4.35%)
inv(16)	46,XY,inv(16)(q22q23.2) (figure 2s)	1 (4.35%)

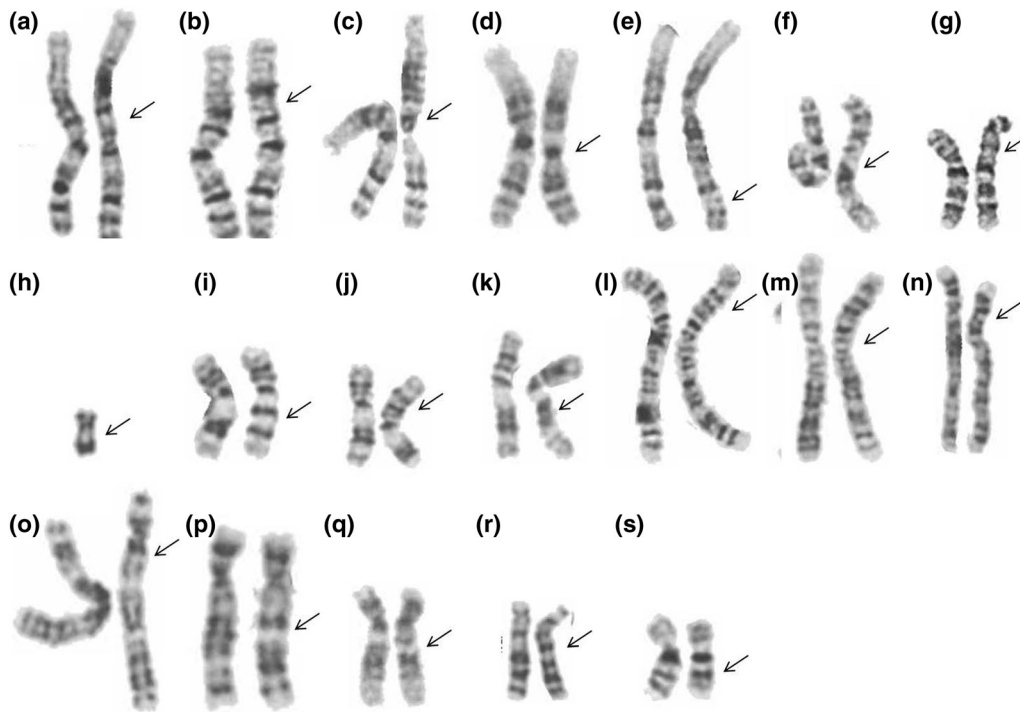


Figure 2. Images of various inversions. The arrows show abnormal chromosomes. (a) $inv(1)(p13.1q12)$, (b) $inv(1)(p22.1p34.1)$, (c) $inv(1)(p11q21)$, (d) $inv(1)(p22q25)$, (e) $inv(1)(q32.1q32.3)$, (f) $inv(10)(q11.2q23.2)$, (g) $inv(10)(p15q21)$, (h) $inv(Y)(p11.2q11.2)$, (i) $inv(11)(q13q21)$, (j) $inv(11)(p15.4q21)$, (k) $inv(11)(q13.2q23.2)$, (l) $inv(2)(p14p16)$, (m) $inv(2)(p11.1q13)$, (n) $inv(4)(p12q21)$, (o) $inv(3)(p23q11.2)$, (p) $inv(5)(p15q32)$, (q) $inv(12)(q13q15)$, (r) $inv(13)(q14.1q21.2)$, (s) $inv(16)(q22q23.2)$.

Table 6. Distribution of karyotypes in $fra(16)$, aneuploidy/mosaic aneuploidy, deletion and marker.

Chromosomal anomalies	Karyotype	Total number of cases	
fra(16)	46,XY,chr(16)(q22)[19]/46,XY[127]	1	
	46,XY,chr(16)(q22)[28]/46,XY,chr(16)(q22)[11]/46,XY[64]	1	
	46,XY,chr(16)(q22)[25]/46,XY,dup(16)(q22)[3]/46,XY[90]	1	
	46,XX,chr(16)(q22)[12]/46,XX,chr(16)(q22)[9]/46,XX[79]	1	
Aneuploidy	47,XXX,1qh+	2	
	45,X[7]/46,XX[83]	1	
	45,X[4]/47,XXX[2]/46,XX[94]	1	
	45,X[12]/46,XX[88]	1	
	47,XXX[7]/45,X[4]/46,XX[89]	1	
	45,X[12]/47,XXX[6]/46,XX[82]	1	
	45,X[20]/46,XX[80]	1	
	47,XXX[7]/46,XX[93]	1	
	45,X[7]/47,XXX[4]/46,XX[89]	1	
	45,X[6]/47,XXX[5]/46,XX[89]	1	
	47,XYY	1	
	Deletion	46,X,del(X)(p22.1)	1
	Marker	47,XX,+mar	1

Discussion

In this study, 2959 couples with spontaneous abortion were detected, and the abnormal rate was 5.85%, much higher than the 0.5% of the normal population, which indicated that chromosomal abnormalities were one of the important causes of spontaneous abortion. The percentage of females carrying chromosomal abnormalities was higher than male, which is

consistent with previous reports (table 7). However, in Sudhir *et al.* (2016), of the 12 patients, eight with chromosomal abnormalities were male four were female. There may be two reasons for this situation, one is due to regional differences, and the other reason may be due to insufficient sample.

Among 2959 couples, the number of spontaneous abortion varied from one to eight abortions/couple. Patients with less than two spontaneous abortions was the main part

Table 7. Review of literature in reproductive disorders.

References	Total couples	Total abnormalities (%)	Structural aberrations	Numerical aberrations	Female/male
Sudhir <i>et al.</i> (2016)	440	12 (2.73%)	12	0	4/8
Dutta <i>et al.</i> (2011)	1162	34 (2.93%)	33	1	21/13
Ayed <i>et al.</i> (2017)	163	10 (6.13%)	6	4	10/0
Tunç <i>et al.</i> (2016)	1510	65 (4.30%)	58	7	40/25
Sheth <i>et al.</i> (2013)	2428	92 (3.79%)	77	15	61/31
Elghezal <i>et al.</i> (2007)	1400	89 (6.36%)	57	32	73/16
Present study	2959	173 (5.85%)	160	13	110/63

(91.31%, 2707/2595), and more than three spontaneous abortions only accounted for 8.69% (257/2959), indicated that the patients paid more attention to the causes of abortion. At the same time, we found that the chromosome abnormality rate of patients with more than three spontaneous abortions was significantly higher than that of patients with less than two spontaneous abortions and chromosome abnormality rate increase significantly with the number of spontaneous abortions, which is consistent with the reports of Asgari *et al.* (2013) and Mogib El-Dahtory (2011).

Among 173 cases of chromosomal abnormalities, structural aberrations were the most common chromosomal abnormalities (160/173), and the incidence (2.70%, 160/5918) was significantly higher than that (0.7%) in normal population (Wang *et al.* 2009). Balanced translocation (58.38%), Robertsonian translocation (17.92%) and inversion (13.29%) were the most common types of chromosomal structural abnormalities. Our results are consistent with previous studies (Dutta *et al.* 2011; Fan *et al.* 2016; Ayed *et al.* 2017).

Balanced translocation means that two chromosomes break at the same time, and the fragments are rejoined to form two derived chromosomes after exchanging positions, without causing an increase or decrease of chromosome fragments. Hundred and one cases of balanced reciprocal translocations were detected. The ratio of female/male carriers was 1.86:1 (65/35). Two proposed mechanism contributing to the higher incidence of female translocation carriers. One is that female translocation carriers release only one mature ovum per month, whereas male carriers release millions of sperm per ejaculation, resulting in possible prezygotic selection against unbalanced gametes (Kochhar and Ghosh 2013). Another may be that the abnormal chromosome structure leads to the decline of male spermatogenesis leading to infertility (Harton and Tempest 2012). We found that balanced reciprocal translocations mainly involved chromosomes 6 and 3. In addition, three rare complex karyotypes were found. All patients were in good health and denied a history of exposure to harmful substances and radiation. The first case is a 33-year-old woman with a karyotype of 45,XX,der(11)t(11;13)(q25;p12),-13; the second patient is a 25-year-old male with a karyotype of 46,XY,inv(10)(q11.23q23.2),t(10;14)(p11.23;q22), and the last patient is a 35-year-old male with a karyotype of

46,XY,inv(4)(q31.1q35),t(8;18)(q13;q12.2). None of the three karyotypes has been reported, so they were especially helpful to supplement the karyotype diversity of patients with chromosomal abnormalities.

Robertsonian translocation is a special kind of balanced translocation, involving only the acrocentric chromosomes. When two acrocentric chromosomes break at the centromere, their long arms join to form a derived chromosome. In our study, 31 cases of Robertsonian translocation were found, among them 12 cases were 45,XN,der(13;14)(q10;q10), accounting for 38.71%, which is well consistent with previous research results (Dutta *et al.* 2011; Sheth *et al.* 2013; Fan *et al.* 2016). Thus, our results further confirm that Robertsonian translocation is most likely to occur on chromosomes 13 and 14.

Inversion is a chromosome that has been broken twice, and the segment between the two breakpoints rotates 180° before reconnecting, leading to the rearrangement of the chromosome gene order. In our study, inversion were found in 23 cases, mainly involving chromosomes 1, Y, 3 and 11. Previous studies also described the presence of chromosomes 1, Y, 3 and 11 inversions in patients with spontaneous abortion (Dutta *et al.* 2011; Tunç *et al.* 2016). In addition, 12 cases were pericentric inversions, nine cases were paracentric inversion in the long arm of chromosome, and in two cases paracentric inversion was detected in the short arm of chromosome, suggesting that the incidence of paracentric inversion in the short arm of chromosome might be lower than that in the other two forms. It is widely known that the role of pericentric inversion 9 variant in spontaneous abortion is controversial. In this study, 28 cases of pericentric inversion 9 variant were detected, and the incidence rate (0.54%, 28/5918) was much lower than that of normal population (1.00–1.65%) (Teo *et al.* 1995), suggesting that the pericentric inversion 9 variant is a normal chromosomal variation.

Summary and conclusion

The prevalence of chromosomal abnormalities in couples with spontaneous abortion in Yantai, Shandong province was 5.85%, indicating that the chromosome abnormality could be one of the important causes of spontaneous

abortion. The rate of percentage of chromosomal abnormalities in females was significantly higher than that of males. The rate of chromosome abnormality was positively correlated with the number of spontaneous abortions. Hence, gender and the number of spontaneous abortions should also be considered in genetic counselling. When one of the partners has chromosome abnormality, preimplantation genetic diagnosis, amniocentesis, or chorionic villus sampling could play a great significance for reducing birth defects.

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Authors' contributions

Z-YM and X-YL wrote the manuscript and coordinated the clinical analysis of the patients.

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