Cytogenetic abnormalities in 222 infertile men with azoospermia and oligospermia in Iran: Report and review

Mohammad T. Akbari, F. Behjati1, G. R. Pourmand2, F. Akbari Asbagh³, M. Ataei Kachoui
Department of Medical Genetics, Faculty of Medical Sciences, Tarbiat Modares University, 1Genetics Research Center, University of Social Welfare and Rehabilitation Sciences, 2Department of Urology, School of Medicine, Tehran University of Medical Sciences, 3Department of Obstetrics and Gynecology, Mirza Kouchak Khan Women Hospital, School of Medicine, Tehran University of Medical Sciences, Tehran, Iran

Original Article

Introduction

Infertility is a common clinical problem. It affects approximately 10%-15% of couples in reproductive age. In half of the couples, causes are male-related, associated with impaired spermatogenesis. There is a complex correlation between genetics and infertility. Several factors affect gametogenesis, from which factors that lead to chromosomal abnormalities are one of the best known. The aim of this study was to determine type and rate of chromosomal abnormalities in infertile azoospermic and oligospermic males in Iranian population.

Materials and Methods

The study was conducted on 222 patients with infertility problems who referred for cyto genetic investigation. The study was approved by the Tehran University of Medical Sciences (TUMS) ethics committee. The referral centers were IVF wards of Mirza Kouchak Khan and Shariati.

BACKGROUND: Infertility affects approximately 10%-15% of couples in reproductive age. In half of the couples, causes are male-related, associated with impaired spermatogenesis. There is a complex correlation between genetics and infertility. Several factors affect gametogenesis, from which factors that lead to chromosomal abnormalities are one of the best known. Some chromosomal aberrations are inherited, while others arise de novo. The result can be failure or a decrease in sperm production, or the production of sperm with an unbalanced chromosomal constitution. The latter may result in unsuccessful conception or in a chromosomally unstable zygote, which in turn may lead to either fetal wastage or the birth of a chromosomally abnormal child. The prevalence varies widely, being less in developed countries and more in developing countries where limited resources for investigation and treatment are available.

There is a complex correlation between genetics and infertility. Several factors affect gametogenesis, from which factors that lead to chromosomal abnormalities are one of the best known. Some chromosomal aberrations are inherited, while others arise de novo. The result can be failure or a decrease in sperm production, or the production of sperm with an unbalanced chromosomal constitution. The latter may result in unsuccessful conception or in a chromosomally unstable zygote, which in turn may lead to either fetal wastage or the birth of a chromosomally abnormal child.

A major area of cyto genetic investigation has been on the nature and frequency of chromosome anomalies associated with azoo- or oligospermia in infertile men. In this study, we report the occurrence of chromosomal aberrations and chromosomal variants by high-resolution banding method in 222 infertile azoospermic and oligospermic men.

Materials and Methods

The study was conducted on 222 patients with infertility problems who referred for cyto genetic investigation. This project was approved by the Tehran University of Medical Sciences (TUMS) ethics committee. The referral centers were IVF wards of Mirza Kouchak Khan and Shariati.
Akbari et al.: Cytogenetic abnormalities with azoospermia and oligospermia

Hospital and Sarem Medical Center. The criterion for infertility was failure of a couple to conceive after 1 year of regular unprotected intercourse. The patients mean age was 34.37 years, and cases were between 20 and 53 years old. Cases that underwent a detailed physical examination and paraclinical investigation (spermiogram, hormonal tests, sonography, and testis biopsy) were recruited into the study. The aims and objectives of the study were explained to the patients who signed written consent. Peripheral blood in 7ml sodium heparin collection tubes were taken from each patient. Cases were classified into groups using sperm count. Azoospermia was defined as the total absence of sperm cells, and oligozoospermia was defined as the sperm cell count less than 20 million/ml in seminal liquid. Azoospermia group involved 132 cases, and oligospermia group involved 90 cases. Except for 4 cases with secondary infertility, the others had primary infertility.

Chromosomal analysis was carried out from cultures of peripheral blood lymphocytes by high-resolution banding (Thymidine method) according to Rooney et al.[4] with minor modifications. The chromosomal aberrations were recorded following the ISCN 2009 guideline.[5] At least 10 well-spread metaphases were analyzed by G-banding, and when required, C-banding (10 cells), Q-banding staining, and NOR were carried out.

Results

The chromosome abnormality rate was 13.96%; the numerical type 12.15% and structural type 1.8% [Table 1]. 27 out of 132 (20.4%) azoospermic males, showed chromosomal alterations, consisting of 25 (18.9%) and 2 (1.5%) numerical and structural abnormality, respectively. Among the 90 oligospermic males, both kinds of chromosome abnormalities were seen in equal number of 2 patients (2.2%). Most of the numerically abnormal patients had classic Klinefelter karyotype (9.45%) [Figure 1]. There were 6 mosaic cases involving X and Y chromosomes (3%). 3 (1.35%) had 47,XXY/46,XY karyotype; whereas each of the karyotypes, 46,XY/46,XX and 47,XXY/46,XX was seen in only 1 patient (0.45%).

1 patient had a deleted Yq(46,XY,del(Y)(q11.2-q11.2), and 2 others were balanced translocation carriers with 46,XY,t(Y;4)(q11.2;p14) and 46,XY,t(X;14) chromosome complements. The last patient with structural aberration had a pericentric inversion involving chromosome 1 with 46,XY, inv(1)(p22;q24) karyotype.

Discussion

In this study as a whole, we observed 13.96% chromosomal abnormality. The prevalence of

![Figure 1: Klinefelter karyotype](image)

**Table 1: Chromosomal abnormalities among 222 infertile men**

| Karyotype | Azoospermia (n/%) | Oligospermia (n/%) | Total (n/%) |
|-----------|------------------|-------------------|-------------|
| 47,XXY    | 21(15.9)         |                   | 21(9.45)    |
| 46,XY/47,XXY | 2(1.5)         | 1(1.1)            | 3(1.35)     |
| 47,XXY/46,XX | 1(0.75)        | 1(0.45)           | 2(0.45)     |
| 46,XY/46,XX | 1(0.75)         | 1(0.45)           | 2(0.45)     |
| 46,XY, t(X;14)(q28;24) | 1(0.75) | 1(0.45) | 1(0.45) |
| 46,XY, t(Y;4)(q11.2; p14) | 1(1.1) | 1(1.1) | 2(1.1) |
| 46,XY, del(Y)(q11.2-q11.2) | 1(1.1) | 1(1.1) | 2(1.1) |
| 46,XY, inv(1)(p22;q24) | 1(0.75) |                   | 1(0.45)     |
| Total     | 27(20.4)         | 4(4.4)            | 31(13.96)   |
chromosome abnormality is higher in infertile men than in normal ones, and it is well-known that the sperm count is inversely related to the existence of chromosomal anomaly.\textsuperscript{[6]} Evaluation of 22 similar studies from the literature including a total of 10,408 cases showed 6.90\% chromosomal anomaly rate [Table 2].\textsuperscript{[7-27]} In our study, 13.96\% of all cases revealed chromosomal alteration. Chromosomal abnormalities are more frequently observed in the population of azo-and/or oligozoospermic males than in the general population.\textsuperscript{[28]} In our study, the highest frequency of abnormal karyotype was among patients with azoospermia (20\%) as compared to the oligospermic subgroup. PY Ng\textit{et al.} reported that the incidence of sex chromosome abnormalities in azoospermia group was higher than that in the oligospermia group.\textsuperscript{[26]} In the present study, chromosomal abnormalities were detected in 20.4\% of 132 azoospermic cases and 4.4\% of 90 oligozoospermic cases. The most common type of karyotype abnormality in infertile cases is represented by Klinefelter's syndrome (KS). The incidence of KS was 9.45\% in our study, which is similar to other studies. KS is the most common abnormality of sexual differentiation, and occurs in approximately 1 in 1000 live births.\textsuperscript{[29]} KS is a form of primary testicular failure with testicular hypotrophy and elevated gonadotropin plasma levels, and it represents the most common form of male hypogonadism.\textsuperscript{[30]} Ceylan\textit{et al.} reported that the prevalence of KS among infertile men is very high, up to 3.3\% in severe oligozoospermia and 26.7\% in azoospermia.\textsuperscript{[25]} It has been always assumed that more than 90\% of non-mosaic 47,XXY males are azoospermic.\textsuperscript{[31]} In our study, we detected that 21 cases had non-mosaic 47,XXY karyotype that all of them belonged to azoospermic subgroup.

Pericentric inversion is one type of chromosomal rearrangement, which has been categorized as a minor chromosomal rearrangement, not expected to associate with abnormal phenotype.\textsuperscript{[6]} However, pericentric inv (1) is a different situation associated with infertility. Chandley\textit{et al.} in their case report study of an oligospermic male with pericentric inv (1) in Pachytene analysis in microspread preparations showed an absence of full loop formation in the inversion bivalent and only the rare occurrence of a partial loop. The majority of the cells exhibited extensive asynapsis across the inverted segment, or a normal looking synaptonemal complex indicative of heterologous pairing along the length of the inversion. Crossing over has been reduced in the No 1

| Author          | Year | No. of cases | Numerical (n/%) | Structural (n/%) | Total (n/%) |
|-----------------|------|--------------|----------------|-----------------|-------------|
| Mau et al.      | 1997 | 150          | 6 (4.0)        | -               | 12 (8.0)    | 18 (12.0)   |
| Tuerlings et al.| 1998 | 1792         | 24 (1.3)       | 6 (0.3)         | 42 (2.3)    | 72 (4.0)    |
| Gunduz et al.   | 1998 | 102          | 13 (12.7)      | -               | 3 (2.9)     | 16 (15.6)   |
| Meschede et al. | 1998 | 432          | 2 (0.4)        | -               | 7 (1.6)     | 9 (2.1)     |
| Pina-Neto et al.| 2006 | 165          | 10 (6.0)       | 3 (1.81)        | 3 (1.81)    | 16 (9.6)    |
| Peschka et al.  | 1999 | 781          | 7 (0.8)        | 4 (0.5)         | 19 (2.4)    | 30 (3.8)    |
| Vutyavanich et al. | 2007 | 130          | 4 (3.07)       | -               | 2 (1.53)    | 6 (4.6)     |
| Nakamura et al. | 2001 | 1790         | 80 (4.4)       | 19 (1.0)        | 126 (7.0)   | 225 (12.6)  |
| Dohle et al.    | 2002 | 150          | 8 (5.3)        | 1 (0.6)         | 7 (4.6)     | 16 (10.6)   |
| Morel et al.    | 2004 | 335          | 2 (0.5)        | -               | -           | 9 (2.6)     |
| Rao et al.      | 2004 | 251          | 8 (3.1)        | 2 (0.7)         | 18 (7.1)    | 28 (11.1)   |
| Clementini et al.| 2005 | 2078         | 6 (0.2)        | 36 (1.7)        | -           | 42 (2.0)    |
| Balkan et al.   | 2008 | 80           | 7 (8.75)       | -               | 2 (2.5)     | 9 (11.25)   |
| Martinez Garza et al. | 2008 | 82          | 6 (7.31)       | 1 (1.21)        | 2 (2.43)    | 9 (10.97)   |
| Nagvenkar et al.| 2005 | 88           | 2 (2.2)        | 3 (3.4)         | 5 (5.6)     | 10 (11.3)   |
| Samli et al.    | 2006 | 819          | 36 (4.3)       | 14 (1.7)        | 17 (2.0)    | 67 (8.1)    |
| Meza-Espinoza et al. | 2006 | 227          | 36 (15.0)      | 5 (2.0)         | 2 (0.8)     | 46 (18.9)   |
| Mohammed et al. | 2007 | 289          | 19 (6.5)       | 3 (1.0)         | 1 (0.3)     | 23 (8.0)    |
| Ceylan et al.   | 2009 | 60           | 10 (16.6)      | 4 (6.66)        | -           | 14 (23.26)  |
| PY Ng et al.    | 2009 | 295          | 10 (3.38)      | 7 (2.37)        | 8 (2.71)    | 25 (8.47)   |
| Akgul et al.    | 2009 | 179          | 16 (8.93)      | 2 (1.11)        | 3 (1.68)    | 21 (11.74)  |
| Kleiman et al.  | 1999 | 133          | 5 (3.7)        | 3 (2.25)        | 3 (2.25)    | 11 (8.27)   |
| Total           |      | 10408        | 317 (3.04)     | 113 (1.08)      | 282 (2.70)  | 719 (6.90)  |
| Our survey      | 1998 | 222          | 27 (12.16)     | 3 (1.35)        | 1 (0.45)    | 31 (13.96)  |
bivalent with only a rare chiasma was seen in the inverted region at metaphase I. Therefore, the cause of infertility is impaired spermatogenesis regardless of breakpoint positioning. In this study, the patient with pericentric inv(1) was in azoospermic subgroup.

Fertility effects of a balanced X-autosome translocation vary depending on the sex of the carrier. In female carriers, gonadal dysgenesis may occur, and ~9% may have multiple anomalies and/or mental retardation. In male carriers, azoospermia is the most common finding, although a few cases have been reported with severe oligozoospermia. The cause of the spermatogenic failure in carriers of an X-autosome translocation is unknown, but spermatogenesis generally is much more sensitive to meiotic disruption than oogenesis due to a number of meiotic cell cycle checkpoints. Rao et al., in their survey, reported an azoospermic patient with 46,XY t(X;15)(q28;q22) karyotype. We also detected 1 case with 46,XY, t(X;14)(q28;q24) karyotype from azoospermic subgroup.

Y chromosome is necessary for male development due to its gene content. SRY and AZFs are also very important. Chromosomal translocations between Y and autosomes are categorized in 3 groups: (1) Involved autosome is an acrocentric and mostly are not problematic, because break point is within the heterochromatin region. (2) Translocations between Y and non-acrocentric autosomes are rare and classically de novo. They usually lead to abnormal phenotypes such as infertility and hypogonadism. (3) The last group is completely rare, and their characteristic is transfer of TDR to an autosome. Kleiman et al. reported a patient with 46,XY, t(Y;4)(q11;q12) karyotype in azoospermic males. In our study, 1 case showed 46,XY, t(Y;4)(q11.2; p14) karyotype who belonged to oligospermic subgroup. In microscopic analysis, it seems that it is a balanced rearrangement; therefore, impaired spermatogenesis is probably due to an inappropriate formation of sex- vesicle and an incomplete formation of X-Y synapses. Because the source of this disorder is the inheritance of a gamete with chromosomal defect from one parent, its occurrence in other family members is possible. Thus, genetic counseling is necessary in these patients.

Kleiman et al reported that Cytogenetic analysis of infertile men revealed that 0.5% had macroscopic deletions of the distal long arm of the Y chromosome (Yq). Infertile men with deletion in proximal region of Yq11 have sertoli cell-only syndrome. Those who have deletion in middle of Yq11 show stopped spermatogenesis and males with deletion in distal part manifest severe oligospermia. In this study, 1 severe oligospermic male (0.45% of total) showed del(Y)(q11.2-q11.2) karyotype. According to his phenotype and the results of testis biopsy, it seems that he belongs to the latter group. In appearance, he was tall with completely defective teeth. It can partly be due to GCY (Growth Control Y chromosome Influence) gene, which is located in Yq11 and is involved in height and tooth size determination.

In the present study, chromosomal abnormalities in mosaic form were also observed, which consisted of 47,XXX/46,XX; 46,XY/47,XXX; 46,XY/45,X in azoospermic subgroup and 46,XY/47,XXX and 46,XX/46,XY in oligospermia cases.

The results of other studies in the literature revealed a mean of 2.70% autosomal and 4.12% gonosomal chromosomal anomaly rate [Table 2]. In our study, those values were 0.45% and 13.51%, respectively. In other surveys among gonosomal chromosomal anomalies, 1.08% was structural and 3.04% was numerical, whereas those values were 1.35% and 12.16% in our study. Comparison of our results with the review of the literature shows a higher incidence (4-fold) of gonosomal, in particular, numerical gonosomal, chromosomal anomalies. In Table 2, in studies with a large sample size but low incidence of total chromosomal abnormality, patients are mostly oligospermic rather than azoospermic, but in surveys with small sample size or a sample size similar to our study, which showed high incidence of total chromosomal abnormality, cases are totally azoospermic or have the same number with oligospermia cases. On the other hand, Morel et al., in their study in the review of the literature, reported that frequency of KS in azoospermia (10.17) is about 19-fold more frequent than in oligospermia (0.57).

In our study, most of the patients belonged to azoospermia subgroup and KS was the most frequent chromosomal abnormality (9.45% of 13.96%), which just observed in azoospermia subgroup. Thus, it seems that high incidence of chromosomal abnormality (13.96%) in our study is due to the number of azoospermic cases.
In conclusion, the results of this study and the review of the literature showed that chromosomal aberrations occur frequently in infertile men, which emphasize the importance of cytogenetic investigation and the relevance of its findings in the patient’s management in the fertility clinics.

**Acknowledgment**

We appreciate the collaboration of the patients and express gratitude to the staffs of the IVF ward of the referral centers of Mirza Kouchak Khan and Shariati Hospital and Sarem Medical Center. We also acknowledge the research deputy of Tehran University of Medical Sciences for providing grant to M. T. Akbari to carry out this study. In our survey, M. T. Akbari designed the research study and directed laboratory work. Professors, G. R. Pourmand and F. Akbari Asbagh managed the patients and selected appropriate patients for this study. F. Behjati was involved in execution and karyotype analysis and M. Ataei Kachouli helped in writing of the manuscript.

**References**

1. Sherrod RA. Understanding the emotional aspects of infertility: Implications for nursing practice. J Psychosoc Nurs. Mental Health Services 2004;42: 40-7.
2. Cates W, Farley TM, Rowe PJ. Worldwide patterns of infertility: Is Africa different? Lancet 1985; 2:596-8.
3. Abramsson L, Beckman G, Duchek M, Nordenson L. Chromosomal aberrations and male infertility. J. Urol 1982;128:52–
4. Rooney DE, Czepulkowski BH. Human cytogenetics, constitutional analysis, a practical approach. IRL Press, Oxford University Press: New York, USA;1992. pp. 39-40.
5. Shaffer LG, Slovak ML, Campbell Lj. ISCN (2009), An International System for Human Cytogenetic Nomenclature. Karger:Basel;2009.
6. Akgl M, Ozkinay F, Erkal D, Cogulu O, Dogan O, Altay B, et al. Cytogenetic abnormalities in 179 cases with male infertility in Western Region of Turkey: Report and review. J Assist Reprod Genet 2009;26:119–22.
7. Mau UA, Bäckert IT, Kaiser P, Kiesel L. Chromosomal finding in 150 couples referred for genetic counselling prior to intracytoplasmic sperm injection. Hum Reprod 1997;12:930–7.
8. Tuerlings JH, de France HF, Hamers A, Hordijk R, Van Hemel JO, Hansson K, et al. Chromosome studies in 1792 males prior to intra-cytoplasmic sperm injection. Eur J Hum Genet 1998;6:194–200.
9. Gündüz G, Lüelec G, Baykara M. Cytogenetic study in 102 infertile men. Urol Int 1998;61:32–4.
10. Meschede D, Lemcke B, Exeler JR, De Geyter C, Behre HM, Nieschlag E, et al. Chromosome abnormalities in 447 couples undergoing intracytoplasmic sperm injection—prevalence, types, sex distribution and reproductive relevance. Hum Reprod 1998;13:576–82.
11. Pina-Neto JM, Carrara RC, Bisinella R, Mazzucatto LF, Martins MD, Sartoratto E, et al. Somatic cytogenetic and azoospermia factor gene microdeletion studies in infertile men. Braz J Med Biol Res 2006;39: 555-61.
12. Peschka B, Leygraaf J, Van der Ven K, Montag M, Schartmann B, Schubert R, et al. Type and frequency of chromosome aberrations in 781 couples undergoing intracytoplasmic sperm injection. Hum Reprod 1999;14:2257–63.
13. Vutyavanich T, Piromlertamorn W, Srirungwiwong S, Sirisukkasem S. Frequency of Y chromosome microdeletions and chromosomal abnormalities in infertile Thai men with oligozoospermia and azoospermia. Asian J Androl 2007; 9:68–75.
14. Nakamura Y, Kitamura M, Nishimura K, Koga M, Kondoh N, Takeyama M, et al. Chromosomal variants among 1790 infertile men. Int J Urol 2001;8:49–52.
15. Dohle GR, Halley DJ, Van Hemel JO, van den Ouwel AM, Pieters MH, Weber RF, et al. Genetic risk factors in infertile men with severe oligozoospermia and azoospermia. Hum Reprod 2002;17:13–6.
16. Morel F, Douet-Guilbert N, Le Bris MJ, Amice V, Le Martelot MT, Roche S, et al. Chromosomal abnormalities in couples undergoing intracytoplasmic sperm injection. A study of 370 couples and review of the literature. Int J Androl 2004;27:178–82.
17. Rao L, Babu A, Kanakavalli M, Padmalatha V, Singh A, Singh PK, et al. Chromosomal abnormalities and y chromosome microdeletions in infertile men with varicocele and idiopathic infertility of South Indian origin. J Androl 2004; 25:147–53.
18. Clementini E, Palka C, Iezzi I, Stuppia L, Guanciali-Franchi P, Tiboni GM. Prevalence of chromosomal abnormalities in 2078 infertile couples referred for assisted reproductive techniques. Hum Reprod 2005;20:437–42.
19. Balkan M, Teker S, Gedik A. Cytogenetic and Y chromosome microdeletion screening studies in infertile males with Oligozoospermia and Azoospermia in Southeast Turkey. J Assist Reprod Genet 2008; 25:559–65.
20. Martinez-Garza SG, Gallegos-Rivas MC, Vargas-Maciel M, Rubio-Rubio JM, Monteros-Rodríguez ME, González-Ortega C, et al. Genetic screening in infertile Mexican men: chromosomal abnormalities, Y chromosome deletions, and androgen receptor CAG repeat length. J Androl 2008;29:654–60.
21. Nagvenkar P, Desai K, Hinduja I, Zaveri K. Chromosomal studies in infertile men with oligozoospermia & non-obstructive azoospermia. Indian J Med Res 2005;122:34–42.
22. Samli H, Samli MM, Solak M, Imirzalioglu N. Genetic anomalies detected in patients with non-obstructive azoospermia and oligozoospermia. Arch Androl 2006;52:263–7.
23. Meza-Espinoza JP, Davalos-Rodriguez IP, Rivera-Ramirez H, Perez-Muñoz S, Rivas-Solis F. Chromosomal abnormalities in patients with azoospermia in Western Mexico. Arch Androl 2006;52:87–90.
24. Mohammed F, Al-Yatama F, Al-Bader M, Tayel SM, Gouda S, Naguib KK. Primary male infertility in Kuwait: A cytogenetic and molecular study of 289 infertile Kuwaiti patients. Andrologia 2007;39:87–92.
25. Ceylan GG, Ceylan C, Elyas H. Genetic anomalies in patients with severe oligozoospermia and azoospermia in eastern Turkey: A prospective study. Genet. Mol. Res. 2009; 8: 915-22.
26. Ng PP, Tang MH, Lau ET, Ng LK, Ng EH, Tam PC, et al. Chromosomal anomalies and Y-microdeletions among Chinese subfertile men in Hong Kong. Hong Kong Med J 2009;15:31-8.
27. Kleiman SE, Yoge\textit{v} L, Gamzu R, Hauser R, Botchan A, Lessing JB, et al. Genetic evaluation of infertile men. Hum Reprod 1999;14:33–8.
28. Chiang HS, Wei HJ, Chen YT. Genetic screening for patients with azoospermia and severe oligo-asthenospermia. Int J Androl 2000;23:20–5.
29. Nussbaum RL, McInnes RR, Willard HF. 6th ed. Thompson & Thompson Genetics in Medicine. Elsevier: Philadelphia:2007.p. 105
30. Lee YS, Cheng AW, Ahmed SF, Shaw NJ, Hughes IA. Genital anomalies in Klinefelter's syndrome. Horm Res 2007;68:150–5.
31. Ferlin A, Arredi B, Foresta C. Genetic causes of male infertility. Reprod Toxicol 2006;22:133–41.
32. Chandley AC, McBeath S, Speed RM, Yorston L, Hargreave TB. Pericentric inversion in human chromosome 1 and the risk for male sterility. J Med Genet 1987;24: 325–34.
33. Kalz-FüEller B, Sleegers E, Schwanitz G, Schubert R. Characterisation, phenotypic manifestations and X-inactivation pattern in 14 patients with X-autosome translocations. Clin. Genet.1999; 55, 362-6.
34. Schmidt M, Du Sart D. Functional disomies of the X chromosome influences the cell selection and hence the X inactivation pattern in females with balanced X-autosome translocations: A review of 122 cases. Am. J. Med. Genet.1992; 42, 161-9.
35. Fraccaro M, Maraschio P, Pasquali F, Scappaticci S. Women heterozygous for deficiency of the (p21 leads to pter) region of the X chromosome are fertile. Hum Genet 1997;39: 283-92.
36. Hunt PA, Hassold TJ. Sex matters in meiosis. Science 2002;296:2181-3.

Cite this article as: Akbari MT, Behjati F, Pourmand GR, Asbagh FA, Kachouli MA. Cytogenetic abnormalities in 222 infertile men with azoospermia and oligospermia in Iran: Report and review. Indian J Hum Genet 2012;18:198-203.
Source of Support: Nil, Conflict of Interest: None declared.