The Effect of Radiation on Secondary Sex Ratio among Radiologists in Shiraz, Iran

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ABSTRACT

Environmental and occupational exposure may play a role in gender offspring. This study aimed to investigate the effect of radiation on gender ratio in the offspring of radiologists and technicians. This cross-sectional study was conducted on 262 participants with a total of 354 children. A data collection form including age, years spent in radiology practice, number of children, sex of each child, observance of radiation protection principles, and intensity of exposure based on International Commission Radiological Protection was completed. Male to female ratio was calculated 0.85 in fathers and 0.75 in mothers in comparison to this ratio estimated in Iran demographic statistics sex ratio which is 1.03. Highly-exposed parents (Prevalence ratio [PR]: 1.67, 95% confidence interval [CI]: 1.11-2.52), as well as fathers (PR: 2.72, 95%CI: 1.56-4.72), had a significant propensity to have female offspring. However, this criterion in female radiologists was not found to be significant (P=0.57). Moreover, in fathers a significant relationship was found between the years spent in radiology field up to the time of the child’s birth or age of the parents’ at child’s conception with offspring gender (4-6 year: PR: 2.07, 95% CI: 1.15-3.72; ≥7 year: PR:1.81, 95%CI: 1.18-2.78). Highly-exposed radiology male personnel, as well as those exposed to radiation 4 years or more before the offspring’s birth, were more likely to have daughters than sons. Although no exact mechanism has been identified for this preponderance, further animal studies are required to evaluate whether x ray is an influential factor in offspring gender.

Key words: Paternal Exposure; Sex Ratio; Radiation; Radiology

INTRODUCTION

Human sex ratio is usually 1050 male to 1000 female[1]. Changes in this ratio prompted us to investigate the influential factors that could play a role in making this ratio skewed. From 1958, the subject of influential factors on offspring gender has been a focus of many studies that led to investigation of the male to female offspring ratio among survivors of Hiroshima and Nagasaki [2]. It has been shown that certain environmental and occupational exposures and endocrine conditions play a role in low propensity for male offspring [3–8] and a statistically significant decline was observed in male to female ratio in the recent 10 years. An opposite radiological hypothesis stated in one study declared that male to female sex ratio increased after radiation effect of Chernobyl nuclear power [9].

Among many factors, in the population with high exposure to Dioxin, mercury and pesticides, a lower proportion of male offspring has been reported [10]. On the other hand, it has been shown that those who were exposed to therapeutic irradiation during childhood did not differ by their offspring gender ratio [11]. Even though a study on low dose ionizing radiation suggests no statistically significant alternation of offspring sex ratio, it has not declined the necessity of more studies [12]. Another study in Japan in 2001 on high radiation-exposed radiologists found the effect of radiation on higher proportion of female offspring. Although no definite mechanism underlying female offspring propensity among radiologists has been identified, radiation-induced mutations in sex chromosomes or endocrine changes have been postulated [3]. Because of ethical problems, most of studies were done on animals and there are few studies on human [13]. Filling the information gap of potential effect of radiation on offspring sex ratio is a key guide for progression in ovulation biology and future population. This is the first study to investigate offspring gender ratio among those who work in radiology clinics in Shiraz and three other cities in Fars province (Iran).
MATERIALS AND METHODS
This cross-sectional study was approved by Shiraz University of Medical Sciences (SUMS) Research Committee. Initially, information was gathered in SUMS Radiology department for all the personnel who work in radiology department. Married radiology specialists or radiology technicians who had worked for at least one year were included. Those who had no child or had no history of intruterine fertilization or in vitro fertilization or gender selection were excluded. Finally, 261 participants who had 354 children participated in this study. Our subjects were all from radiology department in 5 universities, state and private hospitals and 38 private institutes in Shiraz.

A data collection form that addressed the participant’s age and sex, years spent in radiology practice, number of children, sex of each child, observance of radiation protection principles, and intensity of exposure based on International Commission Radiological Protection (ICRP) [14] was completed for our study population. Based on the participant’s history, we classified the intensity of radiation exposure to high and low according to ICRP and asked whether the person has ever received a radiation dose greater than 10 millisievert/year or not. Then, the participants were categorized into highly-exposed and lightly-exposed groups. Moreover, our results were compared with the number of male and female offspring of Iran population that were born during 1974-2014; it was obtained from Iran demographic statistics. Sex ratio was defined as the ratio of male to female offspring. Prevalence ratio [PR] and 95% confidence interval [CI] was used to analyze the data. All statistical evaluations were made assuming a two-sided test based on a 5% level of significance using STATA version 14.

RESULTS

Table 1: Relationship between offspring gender and study variables in total radiologists

<table>
<thead>
<tr>
<th>Variables</th>
<th>Number of male offspring</th>
<th>Number of female offspring</th>
<th>Sex ratio (M/F)</th>
<th>Prevalence ratio</th>
<th>95% CI</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference Population</td>
<td>15709049</td>
<td>15168799</td>
<td>1.035</td>
<td>1.00</td>
<td>1.00-1.00</td>
<td>-</td>
</tr>
<tr>
<td>Study Population</td>
<td>179</td>
<td>175</td>
<td>1.02</td>
<td>1.01</td>
<td>0.82-1.25</td>
<td>0.915</td>
</tr>
<tr>
<td>Radiation Intensity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>36</td>
<td>58</td>
<td>0.62</td>
<td>1.67</td>
<td>1.11-2.52</td>
<td>0.017</td>
</tr>
<tr>
<td>Low</td>
<td>143</td>
<td>117</td>
<td>1.22</td>
<td>0.85</td>
<td>0.66-1.08</td>
<td>0.192</td>
</tr>
<tr>
<td>Parent's age at child's conception (year)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤29</td>
<td>79</td>
<td>76</td>
<td>1.04</td>
<td>1.00</td>
<td>0.73-1.37</td>
<td>1.000</td>
</tr>
<tr>
<td>30-40</td>
<td>61</td>
<td>70</td>
<td>0.87</td>
<td>1.19</td>
<td>0.84-1.67</td>
<td>0.337</td>
</tr>
<tr>
<td>&gt;40</td>
<td>8</td>
<td>6</td>
<td>1.33</td>
<td>0.78</td>
<td>0.27-2.32</td>
<td>0.791</td>
</tr>
<tr>
<td>Duration of exposure* (year)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-3</td>
<td>62</td>
<td>43</td>
<td>1.44</td>
<td>0.72</td>
<td>0.49-1.06</td>
<td>0.098</td>
</tr>
<tr>
<td>4-6</td>
<td>42</td>
<td>55</td>
<td>0.76</td>
<td>1.36</td>
<td>0.91-2.02</td>
<td>0.154</td>
</tr>
<tr>
<td>≥7</td>
<td>60</td>
<td>69</td>
<td>0.87</td>
<td>1.19</td>
<td>0.84-1.68</td>
<td>0.334</td>
</tr>
</tbody>
</table>

*Years spent in radiology field up to time of child’s birth
Note: all analyses were compared with reference population

After initiating their career in radiology field, our study population had 179 male offspring (50.6%) and 175 female offspring (49.4%) (Male/Female ratio: 1.02) (Table 1). Male to female ratio for fathers (Table 2) and mothers (Table 3) were 95:112=0.85 and 63:84=0.75, respectively. Available Iran demographic statistics (1965-2006) demonstrates a rate of 50.9% for male and 49.1% for female offspring, which shows a male/female ratio of 1.03. Although comparison of our study’s population offspring gender with Iran population showed no statistically significant difference (Prevalence ratio (PR): 1.01, 95% confidence interval (CI): 0.82-1.25, P=0.915), when exposure to radiation was classified according to ICRP to low and high, then a statistically significant relationship was found between the intensity of radiation exposure and offspring gender in the total study population (PR:1.67, 95% CI:1.11-2.52, P=0.017) (Table 1). Moreover, fathers with highly radiation intensity had a significant relationship with sex ratio as compared with Iran sex ratio reference population (PR: 2.72, 95% CI: 1.56-4.72, P=0.0005). Additionally, in fathers, years spent in radiology field up to the time of the child’s birth or age of the parents at child’s conception showed a significant relationship with offspring gender (4-6 year: PR: 2.07, 95% CI: 1.15-3.72, P=0.020; ≥7 year: PR: 1.81, 95% CI: 1.18-2.78, P=0.007) (Table 2). However, there was no significant difference between offspring and radiation exposure in mothers (Table 3).

In addition, Iran population offspring gender data was we compared with three different study age groups of ≤29, 30-40 and >40 years in terms of offspring gender, which showed no statistically significant relationship not only in the total radiologists and technicians but also in fathers and mothers radiologist and technicians.
The offspring sex ratio has been studied; for instance, zygotes and embryos with higher sex ratio. However, most of the studies on sex ratio in the offspring of the fathers working with high radiation and the years spent in radiology field had a statistically significant relationship with the offspring’s gender. Due to the concerns about the possible harmful effects of exposure to radiation, this physical agent has been the center of attention in recent years [15,16]. Environmental and occupational exposures have been linked to many genetic mutations, congenital malformation, and also offspring gender ratio. The results of this study were in agreement with those of Hama et al. [3], demonstrating a reduced male offspring proportion in male radiologists. Also, in line with the previously mentioned study, we found that male radiologists who were highly exposed to radiation had a higher propensity to have daughter. Moreover, sex ratio did differ significantly by the years spent in radiology field up to the time of birth of the offspring. It is concluded that exposure intensity may be an influential factor in gender offspring as well as the time interval of exposure duration before the offspring’s birth.

The parents’ age did not affect the gender of the offspring. This finding was consistent with the result of study by Hama et al. [3]. Comparing radiologists with other medical specialists, Choi et al. [17] showed no statistically significant relationship between the male invasive and interventional cardiologists and offspring gender. Cheng et al. [18] found no statistically significant difference between those who worked in and out of operation room. Dickinson et al. [19] in their study on evaluation of the paternal occupation effect on the sex of the offspring did not report a significant relationship between sex ratio and occupation although their study did not report those who worked in radiation exposed medical fields. Aviation officers [20], although not statistically different from general population, were shown to have more daughters than sons (1 male for every 1.002 females). High background radiation [21] has not been associated with altered sex ratio in the offspring of the inhabitants of a northern city of Iran.

The exact mechanism underlying changes in the offspring sex ratio of occupations exposed to x rays has not been found yet, but some have pointed to the possibility of decreased chance of survival for male zygotes and embryos [3]. Another mechanism for offspring sex ratio has been studied; for instance,
Desai et al. [22] have indicated the role of radiofrequency electromagnetic waves in producing reactive oxygen species that cause spermatocys cell death. Among other possible mechanisms, damage to sex chromosomes has been reported [23]. Saadat did not find a skewed offspring gender ratio in men exposed to electromagnetic fields [6], though electromagnetic field exposure was studied to cause abnormal sperm morphology and motility [24]. It has also been suggested that reduced male offspring proportion could be due to reduced rate of fertilization success or decreased chance of spermatoocyte survival [25,26]. Occupational ionizing radiation could lower the secondary sex ratio because of its effect on production or function of gametes [12]. The strengths of this study are as follows: 1) our present study is the first one in Iran which has evaluated the effect of radiation on secondary sex ratio. 2) This study is the representative sample of radiologist in Shiraz, Iran. However, the drawbacks of this study should be noted. 1) Relatively small sample size. The authors would like to suggest that future studies should be conducted with a larger sample. 2) To determine the high and low exposure to radiation based on questionnaire and film-badge dosimeter would be problematic; for example, the radiologist and technicians may not remember the exposure to radiation correctly. Future animal studies should be carried out to determine the effect of x ray on gender of the offspring. Based on different mechanisms involved in these exposures, future studies should be career-specific and include information about occupation of the participant’s spouse. Given the fact that offspring gender is influenced by many factors, further studies should be carried out to study the interaction between influential factors on offspring gender to investigate the factors that play a role in gender propensity in radiology field related jobs.

To conclude, highly-exposed radiology male personnel, as well as those who had been exposed to radiation 4 years or more before field up to the time of the child’s birth or age of the parents’ child’s conception, were more likely to have more daughters than sons. Although no exact mechanism has been identified for this preponderance, further animal studies are required to evaluate whether x ray is an influential factor in offspring gender.

ETHICAL ISSUES
The research was approved by the Ethics Committee of Shiraz university of medical science.

CONFLICT OF INTEREST
The authors have declared no conflict of interest.

AUTHORS CONTRIBUTION
Mahnaz Yadollahi, Mohammad Farahmand and Haleh Ghaem contributed equally to the design of the study along with data analysis, interpretation and preparing the final manuscript. Maryam Foadi, Narges Shamseddini and Mehrdad Karajizadeh contributed to data collection, interpretation and draft manuscript. All of authors approved final manuscript.

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