Awareness Of Pregnant Ladies About The Teratogenic Effects Of X-Ray Exposure: A Cross-Sectional Study In Makkah, Saudi Arabia

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Abstract
Diagnostic X-ray examinations during pregnancy may raise concerns about fetal teratogenicity, and misconceptions can lead to unnecessary anxiety or avoidance of clinically indicated imaging. This study assessed pregnant women's awareness of the teratogenic effects of X-ray exposure, identified common information sources, and explored associated sociodemographic factors in Makkah, Saudi Arabia. A hospital-based cross-sectional study was conducted over six months at Hera Hospital, enrolling pregnant women aged ≥18 years via convenience sampling. Data were collected anonymously using a structured self-administered questionnaire covering sociodemographic and knowledge/perceptions related to X-ray safety in pregnancy. Awareness was quantified using a 0–10 score derived from five true/false items, information sources, and self-rated knowledge, then categorized as low (<6), moderate (6–8), or high (>8). Descriptive analyses were performed, and chi-square testing assessed associations between awareness level and participant characteristics at $p<0.05$. The study included 206 pregnant women; most were aged ≥36 years (77.7%), had at least a bachelor's degree (89.3%), were employed (66.5%), had household income >8000 SAR (74.3%), and were multiparous (73.3%). The mean awareness score was 6.77±1.73 (median 7; IQR 6–8), with 37.4% showing low awareness, 47.6% moderate awareness, and 15.0% high awareness. While many participants correctly rejected the statement that X-rays pose no fetal risk (84.5%) and recognized that high-dose exposure may cause genetic mutations (91.3%), a major gap was observed regarding shielding, as 55.3% believed lead aprons provide complete protection. Healthcare providers were the dominant information source (70.9%), followed by the internet (16.5%), and no significant associations were detected between awareness and age, education, marital status, occupation, income, or parity (all $p>0.05$). Overall, maternal awareness was generally moderate, but persistent misconceptions especially about radiation protection support the need for targeted, evidence-based antenatal counselling and consistent messaging.

BACKGROUND

Pregnancy represents a crucial phase in a woman's life, marked by profound physiological and psychological changes as she nurtures and prepares for the arrival of a new life [1,2]. Prenatal care plays a pivotal role in ensuring the health and well-being of both the mother

and the developing fetus. Among the various aspects of prenatal care, medical imaging techniques such as X-rays are frequently utilized to diagnose and monitor maternal health conditions [3]. However, the use of X-rays during pregnancy raises concerns due to their potential teratogenic effects on the developing fetus.

Medical imaging has revolutionized the field of healthcare by providing clinicians with non-invasive tools to visualize internal structures, detect abnormalities, and guide medical interventions. X-ray imaging, discovered by Wilhelm Conrad Roentgen in 1895, remains one of the most widely used modalities due to its ability to produce high-resolution images of bones, soft tissues, and organs [4,5].

In clinical practice, X-rays are indispensable for diagnosing a myriad of conditions, including fractures, infections, tumors, and pulmonary diseases. The rapid advancements in imaging technology have led to the development of sophisticated X-ray machines that deliver precise images while minimizing radiation exposure [3,5]. Despite these advancements, concerns persist regarding the potential risks of X-ray exposure, particularly during sensitive periods such as pregnancy [6,7].

Teratogenic effects refer to the harmful effects that certain agents, including ionizing radiation from X-rays, can have on the developing fetus during pregnancy [8]. Ionizing radiation has the ability to penetrate tissues and cells, leading to DNA damage, cell death, and disruptions in cellular processes. During pregnancy, the developing fetus is particularly vulnerable to the effects of ionizing radiation due to its rapidly dividing cells and developing organ systems [9,10].

The extent of teratogenic effects depends on various factors, including the dose of radiation, the stage of pregnancy, the specific organs exposed, and the duration of exposure [11]. High doses of ionizing radiation can cause severe developmental abnormalities, miscarriage, or stillbirth, while lower doses may lead to subtle yet significant changes in fetal development, including cognitive impairments and increased cancer risk later in life [10,12].

Maternal awareness of the teratogenic effects of X-ray exposure during pregnancy is a critical aspect of prenatal care [13]. Pregnant women need to be informed about the potential risks associated with X-rays and empowered to make informed decisions regarding diagnostic imaging procedures [14]. However, studies have indicated varying levels of awareness among pregnant women regarding X-ray safety, with gaps in knowledge and misconceptions prevalent in certain populations [15].

Factors influencing maternal awareness include education levels, access to healthcare information, cultural beliefs, previous experiences with healthcare providers, and the quality of patient education and counselling [14]. Improving maternal awareness requires targeted educational interventions, effective communication strategies, and collaboration between healthcare providers and expectant mothers to promote shared decision-making and ensure the safety of both mother and child [13,15].

Makkah, located in the western region of Saudi Arabia, is not only a cultural and religious center but also a hub for healthcare services, catering to a diverse population [16]. The healthcare landscape in Makkah has witnessed significant advancements, with modern facilities and specialized medical centers offering comprehensive maternal and child healthcare [17].

In Makkah, as in many parts of the world, the utilization of medical imaging, including X-rays, is common during pregnancy for diagnostic purposes. However, the level of maternal awareness regarding the teratogenic effects of X-ray exposure in this region remains a topic of interest and concern [16]. Understanding the context-specific factors that influence maternal awareness and attitudes toward X-ray safety during pregnancy in Makkah is essential for designing targeted interventions and promoting safe healthcare practices.

Study Aim

The aim of this study is to assess the awareness of mothers about the teratogenic effects of X-ray exposure during pregnancy in Makkah, Saudi Arabia.

Objectives:

1. To determine the level of awareness among pregnant women in Makkah regarding the teratogenic effects of X-ray exposure.
2. To identify the primary sources from which pregnant women obtain information about X-ray safety during pregnancy in Makkah.
3. To assess the knowledge gaps and misconceptions among pregnant women regarding X-ray exposure risks during pregnancy.
4. To evaluate the association between sociodemographic factors (such as age, educational level, and parity) and maternal awareness levels of X-ray teratogenicity in Makkah.

METHODOLOGY

Study Design

This study employs a cross-sectional design to assess the awareness of mothers about the teratogenic effects of X-ray exposure in Makkah, Saudi Arabia. A cross-sectional design allows for the collection of data at a single point in time, providing insights into the current level of awareness among pregnant women regarding X-ray safety during pregnancy.

Study Duration

The study was conducted over a period of six months. This timeframe allows for comprehensive data collection from pregnant women visiting Hera Hospital in Makkah, KSA, while also accommodating data analysis and reporting within the specified timeline.

Study Setting

The study will take place at Hera Hospital, a reputable healthcare facility in Makkah specializing in maternal and child healthcare services. Hera Hospital is selected as the study setting due to its accessibility to a diverse population of pregnant women and its commitment to providing comprehensive prenatal care.

Sampling and Participant Recruitment

The sampling frame consisted of pregnant ladies aged 18 years and above who are receiving prenatal care at Hera Hospital during the study period.

We will estimate a sample size of 384 participants using the Raosoft ®calculator, with a 5% level of significance, 5% margin of error, 95% confidence, and expected response distribution of 50%.

A convenience sampling method was employed, wherein participants was selected based on their availability and willingness to participate in the study.

Participants was informed about the study objectives, procedures, and potential risks and benefits. Informed consent was obtained from all participants before their inclusion in the study. Exclusion criteria will include pregnant women below 18 years, those with medical conditions impacting their ability to respond accurately, and those declining participation or unable to provide informed consent.

Data Collection

Data was collected using a structured self-administered questionnaire developed specifically for this study. The questionnaire includes two sections: sociodemographic information and maternal awareness of X-ray teratogenicity. The sociodemographic section gathers data on age, educational level, marital status, occupation, monthly household income, and parity.

The maternal awareness section comprises closed-ended questions assessing knowledge and perceptions regarding X-ray safety during pregnancy. Questions cover topics such as the risks of X-ray exposure to the fetus, sources of information, misconceptions, and overall knowledge assessment. The questionnaire is designed to provide a comprehensive understanding of maternal awareness levels and associated factors.

Scoring System

A scoring system is established to quantify maternal awareness levels based on the responses to the questionnaire. Correct answers to questions assessing awareness of X-ray teratogenicity are assigned a score of 1, while incorrect answers receive a score of 0. The total awareness score is calculated by summing up the scores across all relevant questions in the maternal awareness section.

Score Construction: In accordance with previous studies, a comprehensive awareness scoring system was implemented. True/false items (Questions 7, 8, 10, 11, 12) were each scored as 1 point for correct answers and 0 for incorrect answers. Question 9 (information sources) awarded 1 point each for healthcare providers and internet sources, reflecting recognized credible sources. Question 13 (self-rated knowledge) was scored on an ordinal scale: very low (0 points), low (1), moderate (2), high (3), very high (4 points). The total awareness score ranged from 0-10 points.

Awareness Categorization: Tertile-based categorization was employed: Low awareness (score ≤6), Moderate awareness (score 6-8), and High awareness (score ≥8). This approach provides a clinically meaningful tripartite split reflecting the actual score distribution.

Data Analysis

Descriptive statistics were used to summarize sociodemographic characteristics and awareness scores of participants. Inferential statistics, such as chi-square tests or logistic regression, was employed to explore associations between demographic variables and awareness levels. Statistical significance was set at $p < 0.05$.

Ethical Considerations

The study protocol has received approval from the Institutional Review Board (IRB) of Hera Hospital. Ethical considerations include informed consent, confidentiality, voluntary participation, and protection of participants' rights throughout the study. Participants was assured of anonymity, and their data was used solely for research purposes.

RESULTS

The study involved 206 pregnant women attending antenatal care at Hera Hospital in Makkah, Saudi Arabia. The majority of participants were in the age group of 36 years and above (77.7%), with most being employed (66.5%) and possessing a high educational level, as 89.3% had attained at least a bachelor's degree. The predominant monthly household income category was more than 8000 Saudi Riyals (74.3%), and 73.3% of participants were multiparous. The mean total awareness score regarding X-ray teratogenicity was 6.77 (SD = 1.73) out of a maximum of 10 points, with 47.6% of participants demonstrating moderate awareness levels. Healthcare providers were the primary source of information about X-ray safety during pregnancy for the majority (70.9%) of respondents.

As shown in Table 1, the study cohort comprised predominantly women aged 36 years and older, reflecting a mature population of pregnant women seeking prenatal care. The educational composition reveals a highly educated sample, with bachelor's degree holders representing 57.3% and postgraduate degree holders representing 32.0% of the participants. Most participants were married (75.2%), employed (66.5%), with high household incomes exceeding 8000 SAR monthly (74.3%), and predominantly multiparous (73.3%), having experienced two or more previous pregnancies.

This data demonstrates the responses to key assertions regarding X-ray teratogenicity. For the statement 'X-rays do not pose any risks to the developing fetus during pregnancy,' 84.5% of respondents correctly identified this as an incorrect statement, while 15.5% answered incorrectly. This indicates strong understanding among the majority regarding the inherent risks of X-ray exposure. However, regarding the statement 'Lead aprons provide complete protection against X-ray radiation,' only 44.7% correctly answered as incorrect (indicating incomplete protection), while 55.3% incorrectly believed lead aprons provide complete protection, revealing a notable knowledge gap regarding shielding limitations.

Regarding the routine use of X-rays during pregnancy, 83.5% of participants correctly stated that X-rays are not commonly used without adverse effects, demonstrating high awareness of potential risks. In contrast, 91.3% correctly recognized that high-dose X-ray exposure during pregnancy can lead to genetic mutations in the fetus, the highest proportion of correct responses among all knowledge items. For dental X-ray safety during pregnancy, 74.3% correctly identified that it is not completely safe, indicating that the majority understand specific risks in the dental imaging context.

Regarding information sources, healthcare providers were the most frequently cited source of information (70.9%), followed by internet sources (16.5%), others (7.3%), and family members/friends (5.3%). The self-rated overall knowledge assessment revealed that 46.1% of participants rated their knowledge as moderate, 21.8% as high, 17.0% as low, 9.2% as very high, and 5.8% as very low.

The Total Awareness Score was calculated by summing all components, yielding a maximum possible score of 10 points (5 points from true/false items + 1 point from information source + 4 points from self-rated knowledge). The mean total awareness score was 6.77 (SD = 1.73) on a maximum scale of 10 points, with a median of 7.0 (IQR: 6-8). The distribution showed 37.4% with low awareness, 47.6% with moderate awareness, and 15.0% with high awareness.

Chi-square tests were employed to examine the association between awareness levels and sociodemographic characteristics. As presented in Table 3, none of the sociodemographic variables (age group, educational level, marital status, occupation, monthly household income, or number of previous pregnancies) demonstrated statistically significant associations with maternal awareness of X-ray teratogenicity at the $p < 0.05$ level. The p-values for age ($p = 0.6331$), education ($p = 0.1407$), marital status ($p = 0.4638$), occupation ($p = 0.4109$), income ($p = 0.2288$), and parity ($p = 0.2559$) all exceeded the threshold for statistical significance. This finding suggests that maternal awareness regarding X-ray teratogenic effects is relatively uniformly distributed across different demographic categories within this cohort.

Table 1: Sociodemographic characteristics of participants (n=206).

Parameter	Category	No.	Percent (%)
Age group			
	18-24 years	4	1.9
	25-30 years	13	6.3
	31-35 years	29	14.1
	36+ years	160	77.7
Educational level			
	Middle education	2	1.0
	Secondary education	20	9.7

	Bachelor	118	57.3
	Master or higher	66	32.0
Marital status			
	Married	155	75.2
	Single	22	10.7
	Divorced/Separated	19	9.2
	Widowed	10	4.9
Occupation			
	Homemaker	61	29.6
	Employed	137	66.5
	Student	8	3.9
Monthly household income			
	Less than 3000 SAR	13	6.3
	3001-5000 SAR	13	6.3
	5001-8000 SAR	27	13.1
	More than 8000 SAR	153	74.3
Number of previous pregnancies			
	Nulliparous	33	16.0
	Primiparous	22	10.7
	Multiparous	151	73.3

Table 2: Parameters related to awareness of X-ray teratogenic effects among pregnant women (n=206).

Parameter	Category	No.	Percent (%)
Q7: X-rays pose no risk to fetus			
	Incorrect	174	84.5
	Correct	32	15.5
Q8: Lead aprons provide complete protection			
	Incorrect	92	44.7
	Correct	114	55.3
Q10: X-rays used routinely without adverse effects			
	Incorrect	172	83.5
	Correct	34	16.5
Q11: High doses lead to genetic mutations			
	Correct	188	91.3
	Incorrect	18	8.7
Q12: Safe to undergo dental X-rays			
	Incorrect	153	74.3
	Correct	53	25.7
Q9: Sources of information			
	Healthcare providers	146	70.9
	Internet sources	34	16.5
	Others	15	7.3
	Family/friends	11	5.3

Q13: Overall knowledge about X-ray effects			
	Very Low	12	5.8
	Low	35	17.0
	Moderate	95	46.1
	High	45	21.8
	Very High	19	9.2
Total Awareness Score (out of 10)			
	Mean ± SD	6.77 ± 1.73	
	Median (IQR)	7 (6-8)	
	Range	2-10	
Low awareness	77 (37.4%)	Score ≤ 6	
Moderate awareness	98 (47.6%)	Score 6-8	
High awareness	31 (15.0%)	Score ≥ 8	

Table 3: Association between awareness level and sociodemographic characteristics of participants (n=206).

Parameter	Category	Awareness Level (n) Low / Moderate / High	Total	p-value
Age group	18-24 years	1/1/2	4	0.6331
	25-30 years	3/8/2	13	
	31-35 years	11/11/7	29	
	36+ years	62/77/21	160	
Educational level	Middle education	2/0/0	2	0.1407
	Secondary education	9/9/2	20	
	Bachelor	48/56/14	118	
	Master or higher	18/33/15	66	
Marital status	Married	59/73/23	155	0.4638
	Single	5/11/6	22	
	Divorced/Separated	8/10/1	19	
	Widowed	5/4/1	10	
Occupation	Homemaker	28/27/6	61	0.4109
	Employed	47/67/23	137	
	Student	2/4/2	8	
Monthly household income	Less than 3000 SAR	8/5/0	13	0.2288
	3001-5000 SAR	6/6/1	13	
	5001-8000 SAR	12/13/2	27	
	More than 8000 SAR	51/74/28	153	
Number of previous pregnancies	Nulliparous	8/17/8	33	0.2559
	Primiparous	11/9/2	22	
	Multiparous	58/72/21	151	

work plan:

ACTIVITY	Preparation of the proposal	Data collection	Data analysis	Reporting	Final report
MONTH					
Jun 2023					

Jul 2024					
Aug 2024					
Sep2024					
October 2024					
Nov 2024					
Dec 2024					
Jan 2025					
Feb 2025					
March 2025					
Apr 2025					
May 2025					

DISCUSSION

Maternal awareness of the teratogenic effects of exposure to ionizing radiation in the course of pregnancy is a critical element of prenatal care and an essential element of informed decision making in healthcare. The aim of the present study was to determine the level of awareness of pregnant women of Makkah, Saudi Arabia about the risks of teratogens as a result of exposure to X-rays during pregnancy, identify the primary sources of health information, and investigate the possible association between the sociodemographic factors and the level of awareness of pregnant women. This cross-sectional study showed the average total score of awareness among the 206 pregnant women in this study were 6.77 of 10 points and most of them (47.6%) had a moderate level of awareness. Importantly, 37.4% showed low awareness, whereas only 15.0% showed high awareness on the teratogenicity of X-ray. These results are consistent with the accumulating evidence that maternal awareness of radiation risks during pregnancy is less than ideal in many populations. A previous study carried out on radiation exposure in pregnancy found that only 32.92% of the women had knowledge of the ill effects of radiation in pregnancy, and only 27.33% had been previously educated about the same during their antenatal visits [18]. This significant disparity between the results of the current study of awareness levels and awareness standards internationally illustrates the ongoing need for specific health education interventions in the prenatal care setting. The present study identified some important knowledge domains amongst the study population. The highest percentage of correct answers was for high-dose X-ray exposure and genetic mutations since 91.3% of the participants correctly stated that high-dose exposure to X-rays during pregnancy can cause genetic mutations in the fetus. This finding is consistent with the current evidence-based recommendations for the mechanism of teratogenicity by ionizing radiation. Based on existing international recommendations, when the dose is higher than 200 mGy, exposure during the organogenesis period (2-8 weeks after fertilization) is known to cause congenital anomalies, while exposure dose between 60-310 mGy during the fetal period (8-15 weeks) is known to have risk of severe intellectual disability [19]. The American College of Obstetricians and Gynecologists (ACOG) Committee Opinion No. 723 states that the

diagnostic X-ray procedures rarely provide doses high enough to cause damage to the fetus, but rather the risks are carefully weighed against the benefits of obtaining needed diagnostic information [20]. However, the present study showed that there are major knowledge gaps concerning certain aspects of radiation protection. Only 44.7% of the participants indicated that lead aprons do not completely protect against X-ray radiation. 55.3% showed an incorrect response that lead aprons completely protect against X-ray radiation. This misconception is a critical gap of maternal knowledge, as it is an insufficient level of knowledge in regards to the actual protection capacity of shielding measures. Literature shows that whilst lead aprons do offer significant reduction in scatter radiation exposure usually reducing doses by about 6-fold with 0.5mm lead equivalent thickness they do not offer absolute protection, particularly against scattered radiation from all directions [21]. Furthermore, inappropriate fitting of lead aprons can happen in pregnancy because of anatomical changes, which can compromise the protective effect of the lead aprons [22]. This knowledge gap has important clinical implications because pregnant women who become falsely confident about lead protection may needlessly avoid medical imaging procedures that are necessary or they may fail to follow through on any other protective measures. With regard to the specific question of the safety of dental X-rays, 74.3% of the participants correctly stated that dental X-rays are not totally safe during pregnancy, and this suggests that there is considerable awareness in this area. This finding is interesting; however, it should be put in context of current evidence. Dental imaging guidelines confirm minimal radiation doses to the fetus of properly collimated intraoral radiographs will be less than 0.01 mGy (10 microGy) making it one of the safest diagnostic procedures when indicated during pregnancy [23]. The continued sense of dental X-ray danger of 74.3% of respondents may indicate an over-cautious approach that may actually lead to delayed diagnosis of significant dental pathology during pregnancy, a situation that could affect maternal health and in subsequent, the well-being of the fetus. Regarding the sources of health information, healthcare providers were found to be the main source of information with 70.9% of the participants mentioning them to be the main source of information about X-ray safety during pregnancy. This finding proves the important role that healthcare providers play in the maternal awareness and knowledge dissemination. The dependence on healthcare providers as primary source of information is in line with international patterns of research. A thorough research done on maternal health awareness amongst a predominantly Islamic population also found that healthcare providers acted as source of information for maternal health education in 94.3% of instances when women sought counselling [24]. The high volume of pregnant women who acquire information from healthcare providers highlights the importance of ensuring that healthcare providers themselves have accurate and evidence-based knowledge of radiation safety and dose-risk relationships and clinical decision-making. Published evidence suggests that a lot of healthcare providers have misconceptions about radiation teratogenicity and often overestimate the risk to the fetus, potentially leading to an unnecessary amount of anxiety and inappropriate clinical decisions, including counselling towards pregnancy termination, if there is negligible actual risk [25]. The other sources of secondary information found in a present study were internet (16.5%), others (7.3%) and family/friends (5.3%). While the internet is a minority resource in this group, its growing importance in health information seeking is of serious consideration. Recent literature has shown that even though the internet is an accessible source of health information, there is often both an evidence-based and non-evidence-based body of information available that may contribute to health anxiety and perpetuate misconceptions about the risks of radiation [26]. Few reliance on family and friends (5.3%) as information sources indicates that for this Saudi population, informal social networks have a limited role in the information source of awareness

regarding radiation risks during pregnancy which may be due to the preference for consultation with formal healthcare providers which is a feature of healthcare-seeking behavior in this cultural context. In regard to self-assessed overall knowledge, 46.1% of the participants rated their knowledge to be moderate, 21.8% rated their knowledge to be high, 17.0% rated their knowledge to be low, 9.2% rated their knowledge to be very high, and 5.8% rated their knowledge to be very low. The predominance of moderate and high self-rated levels of knowledge assessments is encouraging however when this is interpreted in the context of the objective knowledge scores which indicated that 37.4% had low awareness a notable discrepancy is revealed.

This divergence between self-perceived and objectively measured knowledge represents an important finding, suggesting potential overestimation of knowledge by some participants. Such discrepancies between subjective and objective health literacy have been documented in international maternal health research and may reflect the Dunning-Kruger effect, wherein individuals with limited knowledge may systematically overestimate their level of understanding [27]. This observation has practical implications for designing health education strategies, suggesting that interventions should incorporate mechanisms for objective knowledge assessment and corrective feedback rather than relying solely on self-reported awareness.

In examining associations between sociodemographic variables and maternal awareness levels, the present study found no statistically significant relationships between any demographic characteristic (age, education, marital status, occupation, household income, or parity) and awareness of X-ray teratogenicity. Chi-square testing revealed p-values exceeding 0.05 for all demographic variables examined (age $p=0.6331$; education $p=0.1407$; marital status $p=0.4638$; occupation $p=0.4109$; income $p=0.2288$; parity $p=0.2559$), indicating that awareness levels were relatively uniformly distributed across different demographic categories. This finding is noteworthy and somewhat unexpected, as educational level typically demonstrates strong associations with health knowledge in many populations. However, this observation is not without precedent in the literature. Other investigations have similarly found no significant association between sociodemographic factors and specific aspects of pregnancy-related health knowledge, particularly in highly educated populations [28]. The relatively high educational level of the present study population (89.3% possessed at least a bachelor's degree) may have resulted in a ceiling effect, wherein most participants achieved similar baseline knowledge levels regarding radiation risks regardless of demographic differences. Alternatively, the uniform distribution of awareness across demographic categories may reflect effective health messaging and accessibility to health information that transcends typical sociodemographic barriers within this healthcare setting in Makkah.

The present study's findings contribute meaningfully to the growing evidence base regarding the current state of maternal awareness about radiation safety during pregnancy in the Middle East region. The overall moderate awareness level with 47.6% demonstrating moderate awareness suggests that while pregnant women in this setting possess basic knowledge about radiation risks, substantial opportunities exist for targeted educational interventions to enhance understanding and correct existing misconceptions. International guidelines and expert consensus emphasize that despite the potential teratogenic effects of ionizing radiation at very high doses (>0.5 Gy), the doses delivered by diagnostic X-ray procedures rarely pose appreciable risk to the fetus [24]. A cumulative radiation dose of less than 100 mGy to the fetus carries negligible risk at any stage of pregnancy, and diagnostic X-rays typically deliver fetal doses far below this threshold [25]. Pregnant women and healthcare providers alike would substantially benefit from accurate, evidence-

based information regarding these safe exposure thresholds to prevent unnecessary anxiety, inappropriate clinical decisions, and unnecessary terminations of wanted pregnancies.

The findings of the present study underscore the critical importance of providing pregnant women with accurate, evidence-based information about radiation safety and the actual risks associated with diagnostic imaging during pregnancy. The demonstrated reliance on healthcare providers as the primary information source necessitates that these providers themselves receive continuing education about current radiation safety guidelines, dose-risk relationships, and the principles of ALARA (As Low As Reasonably Achievable) in clinical practice. Additionally, the significant knowledge gap regarding lead apron limitations highlights the need for specific, targeted education about protective measures and their actual effectiveness. Furthermore, interventions targeting maternal awareness should emphasize that diagnostic X-ray exposure, when appropriately indicated and properly performed with optimization techniques, poses minimal risk to the developing fetus, while delayed diagnosis of maternal pathology may pose greater cumulative risks to both mother and child. Education should also address common misconceptions, including the false belief that lead aprons provide complete protection and that dental X-rays pose substantial risk.

The main limitations of the present study merit careful consideration. First, the cross-sectional design limits our ability to establish causality or temporal relationships between awareness variables and other clinical or demographic factors. Second, the study was conducted in a single healthcare facility (Hera Hospital) in Makkah, potentially limiting generalizability to other geographic regions in Saudi Arabia or other countries with different healthcare systems, healthcare delivery models, and patient populations with varying sociocultural contexts. Third, the high educational level of the study population (89.3% with at least a bachelor's degree) may not be representative of all pregnant women in Saudi Arabia, potentially limiting the applicability of findings to populations with lower educational attainment or different socioeconomic backgrounds. Fourth, the reliance on self-reported questionnaire data introduces the possibility of recall bias or social desirability bias, wherein participants may respond in ways they believe are expected by researchers rather than providing truthful responses.

CONCLUSION

In this hospital-based survey of 206 pregnant women in Makkah, overall awareness of X-ray teratogenicity was moderate (mean 6.77/10), yet 37.4% had low awareness. The most important gap was misunderstanding of radiation shielding, as 55.3% believed lead aprons provide complete protection. Healthcare providers were the main information source (70.9%), so consistent counselling and staff continuing education on dose–risk concepts and ALARA are essential. Antenatal materials should correct misconceptions about dental radiography, explain when imaging benefits outweigh fetal risk, and encourage shared decision-making. Because the study used a single-centre, convenience sample and a cross-sectional design, broader multi-site research is needed to test generalizability and evaluate targeted educational interventions. Future programs can leverage provider-led brief counselling at imaging referral points, complemented by vetted online content, to reduce anxiety, prevent unnecessary imaging refusal, and promote timely diagnosis of maternal conditions during pregnancy. Routine evaluation of knowledge after counselling would help verify learning outcomes.

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