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REVIEW ARTICLE

A REVIEW ON DIAGNOSTIC DENTAL RADIATION RISK DURING PREGNANCY: JUSTIFYING THE DILEMMA-REVIEW

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ABSTRACT

Pregnancy is accompanied by a variety of physiologic, anatomic and hormonal changes that can affect the oral health. However, these patients are not medically compromised and should not be denied dental treatment simply because they are pregnant. They often pay visits to dentist for pain and infections associated with their teeth. Such patients need dental treatment and in most cases the radiograph of the involved tooth is required. It is repeatedly reported that dentists post-pone dental treatments to the period after delivery because of the insufficient knowledge of the low doses involved in diagnostic dental radiation. The delay in treatment might have adverse effects on the mother and the fetus. It is estimated that there is a one-percent increase in congenital abnormalities subsequent to an exposure of 10 rads (100 mGy) of fetal dose. Since diagnostic doses are less than 10 rads in dentistry, such abnormalities cannot be attributed to dental diagnostic doses. This article justifies with literature evidence that dental x rays are not harmful during pregnancy, provided that the dentist follows all the proper radiologic practices with respective guidelines.

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INTRODUCTION

Pregnancy causes many changes in the physiology of the female patient. These alterations are sometimes subtle but can lead to disastrous complications if proper precautions are not taken during dental treatment (Turner, 2002). Physiologically, changes occur in the cardiovascular, hematologic, respiratory, gastrointestinal, genitourinary, endocrine, and oro-facial systems (Suresh, 2004). The local physical changes occur in different parts of the body, which include the oral cavity. These collective changes may pose various challenges in providing dental care for pregnant patients and in most cases the radiograph of the involved tooth is required (Kurien, 2013). It is repeatedly reported that dentists postpone dental treatments to the period after delivery because they do not have sufficient knowledge of the low doses involved in diagnostic dental radiation(4). The delay in treatment might have adverse effects on the mother and the fetus. Therefore, understanding the physiologic changes of the body and the effects of dental radiation which are used in dentistry for the pregnant women and the fetuses, is essential for the management of the pregnant mothers.

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Radiological considerations

Ionizing Radiation

The term *radiation* literally, refers to energy transmission and thus is often applied not only to x-rays, but also to microwaves, ultrasound, diathermy, and radio waves (Freeman, 1994). Of these, x-rays and gamma rays have short wavelengths with very high energy and are ionizing radiation forms. The other four energy forms have rather long wavelengths and low energy (Brent, 1999, 2009) (Freeman, 1994). The biological effects of x-rays are caused by an electro chemical reaction that can damage tissue.

According to Brent (1999, 2009), x-rays and gamma-radiation at high doses can create two types of biological effects and reproductive risks in the fetus:

Deterministic effects: These may cause congenital malformations, fetal-growth restriction, mental retardation, and abortion. Although controversial, this so-called NOAEL— No Observed Adverse Effect Level—suggests that there is a threshold dose (0.05 gray or 5 rad) (Tarsitano, 1993) below which there is no risk. It also suggests that the threshold for

gross fetal malformations is more likely to be 0.2 gray (20 rad).

Stochastic effects: These are randomly determined probabilities, which may cause genetic diseases and carcinogenesis. In this case, cancer risk is increased, and hypothetically, at even very low doses. In this sense, ionizing radiation refers to waves or particles - photons of significant energy that can change the structure of molecules such as those in DNA, or that can create free radicals or ions capable of causing tissue damage (Hall, 1991; National Research Council, 1990) (Livingston, 1998). The standard terms used are *exposure* (in air), *dose* (to tissue), and *relative effective dose* (to tissue). In the range of energies for diagnostic x-rays, the dose is now expressed in grays (Gy), and the relative effective dose is now expressed in sieverts (Sv) (American Academy on Pediatric Dentistry Council on Clinical Affairs Committee on the adolescent, 2008). These can be used interchangeably.

X-Ray Dosimetry

When calculating the ionizing radiation dose, such as that from x-rays, several factors to be considered include:

- Type of study,
- Type and age of equipment,
- Distance of target organ from radiation source,
- Thickness of the body part penetrated, and
- Method or technique used for the study (Wagner, 1997) (ADA, 2001).

Estimates of dose to the uterus and embryo for various frequently used radiographic examinations are summarized in Table 1.

Table 1. Comparison between various radiologic exposures and estimated embryonic or fetal dose

Source of Radiation	Dose (mrad)
Skull	<0.01
Cervical spine	<0.01
Thoracic spine	0.6
Chest	0.06
Upper GI	48
KUV	263
IVP	814
Pelvis	194
Computed tomography (Gonad dose for a total scan)	0.1
Daily (cosmic) background radiation	0.01

Abbreviations: GI-gastrointestinal, KUB-kidney, ureter and bladder, IVP-Intravenous Pyelogram.

Studies of maternal body parts farthest from the uterus, such as the head, result in a very small dose of radiation scatter to the embryo or fetus. The size of the woman, radiographic technique, and equipment performance are variable factors. Thus, data in the table serve only as guidelines. When the radiation dose for a specific individual is required, a medical physicist should be consulted. Brent (Freeman, 1994), (2009) recommends consulting the Health Physics Society website (www.hps.org) (Baykus, 2012), to view some examples of questions and answers posed by patients exposed to radiation.

Deterministic Effects of Ionizing Radiation

One potential harmful effect of radiation exposure is deterministic, which may result in abortion, growth restriction, congenital malformations, microcephaly, or mental retardation. These deterministic effects are threshold effects, and the level below which they are induced is the NOAEL (Brent, 2009). The harmful deterministic effects of ionizing radiation have been extensively studied for cell damage with resultant embryogenesis dysfunction. These have been assessed in animal models, as well as in Japanese atomic bomb survivors and the Oxford Survey of Childhood Cancers (Sorahan, 1995) (Cetin, 2005). Additional sources have confirmed previous observations and provided more information (Groen, 2012) (Chellakooty, 2004). One is the 2003 International Commission on Radiological Protection publication, which describes biological fetal effects from prenatal irradiation and another is the Biological Effects of Ionizing Radiation—BEIR VII Phase 2 report of the National Research Council (2006) (Conrad, 2013), which discusses health risks from exposure to low levels of ionizing radiation, and new data on both epidemiological and experimental research. Mainly the ionizing radiation arises from both man-made and natural sources and at very high dose can produce damaging effects in human tissues that can be evident within few days after exposure.

Stochastic Effects of Ionizing Radiation

This refers to random, presumably unpredictable oncogenic or mutagenic effects of radiation exposure. They concern associations between fetal diagnostic radiation exposure and increased risk of childhood cancers or genetic diseases. According to Doll and Wakeford (1997) (Conrad, 2005), as well as the National Research Council (2006) BEIR VII Phase 2 report, excess cancers can result from in utero exposure to doses as low as 0.01 Sv or 1 rad. Stated another way by Hurwitz and colleagues (2006) (Conrad, 2011b), the estimated risk of childhood cancer following fetal exposure to 0.03 Gy or 3 rad doubles the background risk of 1 in 600 to that of 2 in 600 (Table 1). In one report, in utero radiation exposure was determined for 10 solid cancers in adults from age 17 to 45 years. There was a dose-response relationship as previously noted at the 0.1 Sv or 10 rem threshold. Intriguingly, nine of 10 cancers were found in females (National Research Council, 2006)[(20)]. These likely are associated with a complex series of interactions between DNA and ionizing radiation. They also make it more problematic to predict cancer risk from low-dose radiation of less than 0.1 Sv or 10 rem. Importantly, below doses of 0.1 to 0.2 Sv, there is no convincing evidence of a carcinogenic effect (Brent, 2009; Preston, 2008; Strzelczyk, 2007).

Diagnostic Radiation

To estimate fetal risk, approximate x-ray dosimetry must be known. According to the American College of Radiology no single diagnostic procedure results in a radiation dose significant enough to threaten embryo-fetal well-being (Hall, 1991) (Farage, 2011). Radiographs in pregnancy, the AP-view chest radiograph is the most commonly used study, and fetal exposure is exceptionally small 0.0007 Gy or 0.07 mrad. With one abdominal radiograph, the embryo or fetus is directly in the x-ray beam, (Table 1). The dose is higher 0.001 Gy or 100 mrad. The standard intravenous pyelogram may exceed 0.005 Gy or 500 mrad because of several films. Most "trauma series," such as radiographs of an extremity, skull, or rib series, deliver low doses because of the fetal distance from the target area. Fetal indications for radiographic studies are limited. In

some countries, x-ray pelvimetry is done for a brief presentation. Kusama et al., (Feletou, 2006), indicated that the fetus does not directly receive radiation doses during head and chest diagnostic exposures and that the absorbed dose was estimated at less than 0.01 mGy. It was concluded that in women who were unaware of their pregnancy and who had been exposed to radiation, there is no need for pregnancy termination when the exposure dose to the fetus is less than 100 mGy. Nonetheless, no radiography procedure should be carried out on pregnant women unless there is an absolute necessity. All techniques for minimizing the absorbed dose should be undertaken when such radiographs are mandated. Radiographs should be provided with well-collimated beams in precisely-protected shields. A high-kVp technique is appropriate in such cases (Gambling, 2011).

Guidelines for diagnostic imaging during pregnancy

The American College of Obstetricians and Gynecologists (2009) (Guyton, 1981), has reviewed the effects of radiographic, sonographic, and magnetic-resonance exposure during pregnancy. Its suggested guidelines are as follows.

Guidelines for Diagnostic Imaging During Pregnancy

- Women should be counseled that x-ray exposure from a single diagnostic procedure does not result in harmful fetal effects. Specifically, exposure to less than 5 rads has not been associated with an increase in fetal anomalies or pregnancy loss.
- Concern about possible effects of high-dose ionizing radiation exposure should not prevent medically indicated diagnostic x-ray procedures from being performed on a pregnant woman. During pregnancy, other imaging procedures not associated with ionizing radiation, e.g., ultrasonography, and MRI, should be considered instead of x-rays when appropriate.
- Ultrasonography and MRI are not associated with known adverse fetal effects.
- Consultation with an expert in dosimetry calculation may be helpful in calculating estimated fetal dose when multiple diagnostic x-rays are performed on a pregnant patient.
- The use of radioactive isotopes of iodine is contraindicated for therapeutic use during pregnancy.
- Radiopaque and paramagnetic contrast agents are unlikely to cause harm and may be of diagnostic benefit, but these agents should be used during pregnancy only if the potential benefit justifies the potential risk to the fetus.

Summarized from the American College of Obstetricians and Gynecologists, 2009 (Helal, 2012).

Radiographs, pregnancy and the fetus

X-rays are a type of electromagnetic radiation that have the ability to ionize the material through which it passes. Ionization of living matter results in a damage to the cells or the DNA (Henry, 2012). Depending on the amount of radiation and the stages of pregnancy, damage to the fetal cells may result in miscarriages, birth defects or mental impairment. However the dental radiation exposure of the fetus is negligible (Hibbard, 2014). The embryo and the fetus, being much more radiosensitive than the adult counterpart, are susceptible to adverse effects which result from the radiography exposure. During the first 2 weeks after the conception, the patient may have no knowledge of being pregnant, thus making it prudent for the physician to inquire about the last menstrual period before obtaining a radiographic image. Because a general questioning does not give a definitive diagnosis about the pregnancy status, a lead shielding should be used for all the women who are in their childbearing years (Inoue, 2007). The frequency of mutations and adverse effects is directly related to the dose, and the exposure is augmented when higher than necessary radiation exposures are used to compensate for the inadequate processing quality. The exposure can also be increased, depending on the view which is taken. The radiations from the maxillary anterior views may pass through the abdominal area, with penetration from the primary beam, as well as from the scatter /radiation. Depending on the head position, a similar exposure could also occur with the posterior views. Several precautions can be taken to avoid the fetal exposure when radiographs needed (Jeffreys, 2006). Using a lead shield over the patient's abdomen, using a properly collimated beam, and using a high-speed film, can reduce the foetal exposure.

The teratogenicity of the radiation depends on the fetal age and the dose of the radiation. The greatest risk to the fetus for teratogenicity and death, is during the first 10 days after the conception (Kaňová, 2011). The most critical period of the fetal development is between 4-18 weeks after the conception. The National Commission for Radiation Protective (NCRP) (Kennedy, 2010), recommends that the cumulative fetal exposure to radiation should not exceed more than 0.20 Gy, which can cause microcephaly and mental retardation. CT is quite useful for localizing deep-seated infections and it is the modality of choice for viewing the lateral pharyngeal infections. The definition of the internal anatomy is superior to the plain film radiographs, and the bony changes are seen quite well. The CT doses are higher than those of plain radiography, but they are lower than the multiple slices for polytomography (Kenny, 2014). The CT doses depend on a variety of factors, which include the scanner type, the scanning technique, the exposure settings, the number of slices, and the slice thicknesses. The skin doses from CT can range from 0.4 to 4.7 rads, with most of the machines delivering in the 2.5 – rad range. The combined axial and coronal images require from 3.5 to 5.0 rads (Kulandavelu, 2013). However, the gonadal dose has been shown to be less for a total scan, and it ranges from 0.1 to 0.3mrads. These doses to the fetus can be kept to a minimum by carefully using the shielding devices. Moreover, if the diagnostic irradiation provides crucial information for the maintenance of the maternal and fetal viabilities, the benefits outweigh the risks of the exposure. MRI may be an alternative to CT when the fetal irradiation is considered. MRI has a greater soft tissue sensitivity and contrast as compared to CT, and thus it may help even more in the difficult cases of infections. MRI uses a magnetic field-assisted nuclear alignment in creating images. However, the risks of the fetal exposure to the strong magnetic fields are not completely known.

Oral Radiography

Oral radiography is considered safe for pregnant patients, provided protective measures such high-speed film, a lead apron and a thyroid collar are used. No increase in congenital

anomalies or intrauterine growth retardation has been reported for x-ray radiation exposure during pregnancy, totaling less than 5–10 cGy and a full-mouth series of dental radiographs results in only 8×10^{-4}cGy (Leung, 2012). A bitewing and panoramic radiographic study generates about one-third the radiation exposure linked with a full-mouth series with E-speed film and a rectangular collimated beam. Patients who are concerned about radiography during pregnancy should be reassured that in all cases requiring such imaging, the dental staff will practice the ALARA (As Low As Reasonably Achievable) (Leung, 2011) principle and that only radiographs necessary for diagnosis will be obtained.

Justifying the use of *dental Xrays* in Pregnant patients

Justification 1: According to the American College of Radiology, no single diagnostic x-ray involves a radiation dose significant enough to pose a threat to the health and Normal development of the fetus (ACOG 2004) (Lindheimer, 2010).

Justification 2: More recent evidence New York State Department of Health suggests that ionizing radiation at a dose of less than 5 rad does not increase the risk of malformation, growth retardation or miscarriage (NYSDH 2006) (Lipiński, 2013).

Justification 3: NOAEL— No Observed Adverse Effect Level—suggests that there is a threshold dose (0.05 gray or 5 rad) below which there is no risk (Brent *et al* 2009) (Freeman, 1994). It also suggests that the threshold for gross fetal malformations is more likely to be 0.2 gray (20 rad).

Justification 4: According to Doll and Wakeford (1997) (Lippi, 2007), as well as the National Research Council (2006) BEIR VII Phase 2 report, excess cancers can result from in utero exposure to doses as low as 0.01 Sv or 1 rad. Stated another way by Hurwitz and colleagues (2006) (LOnberg, 2003),the estimated risk of childhood cancer following fetal exposure to 0.03 Gy or 3 rad doubles the background risk of 1 in 600 to that of 2 in 600.

Justification 5: In pregnancy, the AP-view chest radiograph is the most commonly used study, and fetal exposure is exceptionally small 0.0007 Gy or 0.07 mrad. With one abdominal radiograph, because the embryo or fetus is directly in the x-ray beam, the dose is higher 0.001 Gy or 100 mrad[(51)]. The National Commission for Radiation Protective (NCRP 2000)[(40)] recommends that the cumulative fetal exposure to radiation should not exceed more than 0.20 Gy, which can cause microcephaly and mental retardation. Most "trauma series," such as radiographs of an extremity, skull, or rib series, deliver low doses because of the fetal distance from the target area (Flynn *et al* 2007) (Mor, 2011).

Justification 6: However, if dental X-rays prove necessary, they should be obtained under adequate safety conditions (beam collimation, high-speed film,filter, lead protection, high kV setting or constant beams,in-use quality program), No increase in congenital anomalies or intrauterine growth retardation has been reported for x-ray radiation exposure during pregnancy, totaling less than 5–10 cGy (Muallem, 2006) and a full-mouth series of dental radiographs results in only 8×10^{-4}cGy.A bitewing and panoramic radiographic study generates about one-third the radiation exposure linked with a full-mouth series with E-speed film and a rectangular Collimated beam and only selected peri apical or bitewing images should be contemplated in most cases.

Conclusion

Pregnancy is a unique period with many physiologic changes that leads to the formation and maturation of a new life. Every pregnant women should be encouraged to seek medical and dental care during pregnancy, as a failure in treating the developing problems affects the health of both the mother and the unborn child. The dental care professionals must gain a basic understanding of the underlying physiological changes of pregnancy, the influences which are related to the use of medications during pregnancy, radiological considerations ,and how these may interact with the delivery of dental care. This understanding aids the development of the treatment plan and the delivery of the necessary medical, nutritional and dental care, as well as it prepares the professionals for counseling their pregnant patients. Hereby we conclude that dental radiographs are considered safe to be given at any time that it is deemed necessary during pregnancy, provided that the dentist follows all the proper radiologic practices, i.e., using a radiation protective apron with a thyroid collar, using high-speed films, following the proper procedures in order to take the radiograph, and following the ALARA (As Low As Reasonably Achievable) principle (ADA 2006).

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