Journal of Surgery and Trauma 2018; 6(3):77-85

www.jsurgery.bums.ac.ir

REVIEW ARTICLE

A narrative review on the Radiation Risk of Medical Imaging for traumatic pregnant patient and the fetal risks

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Received: October 6, 2017 ***Revised: December 23, 2017*** ***Accepted: June 17, 2018***

Abstract

Introduction: The incidence rate of trauma in pregnancy is about 5 to 7 percent. More than 50% of the trauma during pregnancy is caused by motor vehicle accidents, and about 80% of fetal deaths occur during these automobile accidents. A traumatic pregnant woman should be visited and evaluated typically because placental abruption can have sudden consequences for the fetus with or without signs. Management strategies of maternal trauma should be reliant on accurate assessment of the mother. In order to accurately assess the patient's trauma, it is essential to provide a medical image of the patient. Radiography and CT scan are the first, fastest and most accessible imaging techniques in most health centers. Imaging techniques based on ionizing radiation present hazards and harmful effects to living organisms. The risk of ionizing radiation during pregnancy is highly dependent on the absorption dose and the age of the fetus. Absorbed doses for different radiographic examinations are different. The aim of this study was to evaluate the received radiation dose by the pregnant traumatic patient, and secondly assess the received dose by the fetus.

Methods: In this narrative review, we concentrated on literature in three fields relating to firstly traumatic pregnant patients, secondly ionizing radiation dose from different medical imaging and finally, fetal dose and risk.

Results: Depending on the type of radiography, the dosage of the embryo is also different. For example, examinations in which the embryo is placed on the pathway of the primary beam increases the received dose. Considering the harmful effects of ionizing radiation in imaging traumatic patients with a large number of images, the examinations that include the abdominal and pelvic region should be justified in detail. And, as far as possible, use non-ionizing imaging techniques instead of ionizing methods. One of the most reliable methods for reducing fetal doses is the development and promotion of non-ionizing imaging methods in traumatic pregnant women, such as ultrasound and MRI.

Conclusions: All efforts should be made on the pregnant women in such a way that the embryo dose is as low as possible. It is strongly recommended that physician and medical team staff have a good knowledge and attitudes towards the radiation protection principles and in practice use standard of radiation protection safety principles.

Key Words: Multiple Trauma; Pregnancy; Radiation; Ionizing; Radiation Dosage; Fetus

Introduction

Multiple Trauma is a medical term describes the condition of a patient who has been damaged and exposed to multiple traumatic injuries(1). The first phase of emergency treatment of a patient who has been seriously injured from trauma is to properly evaluate the patients. Early deaths may occur minutes to hours after the injury, hence primary assessment of trauma patients is a crucial

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task, and every minute can be a narrow band between life and death (2). For peoplebetween ages 1-44 years old trauma is the first cause of death, however in all age groups cancer and atherosclerotic disease is more than traumain both developed and developing countries (3). Multiple trauma mortality can be categorized in three immediate, early and late deaths. fatal injuries togreat vessels, heart and brain can lead to immediate deaths. Deaths that happens minutes to hours after the injury called early deaths.The last category of multiple trauma deaths is late mortality that is occurs from days to weeks after injury, mainly because of sepsis and multiple organ failure. Emergency staffs trying to rescue patients from early trauma mortality; whereas, critical care is designed to prevent later trauma mortality.

The main tool in multiple trauma care is the medical imaging to detect different traumas. Diagnostic and treatment modalities strongly depend on the medical centers facilities and the physician'sdecision(4-7). Among the different modalities emergency physicians and trauma surgeons extensively use radiography as the first steps in diagnosis and treatment of seriously injured multiple trauma patients because of its acute evaluation, availability and inexpensively(8-12).At the trauma room, clinical examination is often complemented with plain radiographs of the chest and pelvis, and according to standard protocol of care for trauma patients followed by CT imaging, oftena whole body computed tomography (WBCT) including the head, neck, chest, abdomen, and pelvis (13-20). By the reviews like this study could be able to provide some important information for physicians to be cautious about the prescription of non-ionizing imaging method instead of using ionizing imaging methods. Using of non-ionizing radiation leads to reduction in doses for traumatic pregnant patient and their fetus.

Methods

Although this study is a narrative review, researchers tried to become close to steps of a systematic review. However, authors do not claim for performing a systematic review. in this study, we concentrated on literature in three fields relating to firstly, traumatic pregnant patients, secondly ionizing radiation dose from different medical imaging and finally, fetal dose and risk. Considering above mentioned fields, using keywords: "multiple traumatic pregnant patient", "ionizing radiation dose", "radiation risk", "fetus dose", and "medical imaging absorb dose" in databases and search engines listed as: web of science, PubMed and Google Scholar were searched for related articles. Original research articles and review articles in English or Farsi language were included. Also, articles in other language with English abstract if needed were included. Other types of articles like letter to editor, commentary, book review etc. were excluded. In order to achieve the best results, no time limit was applied. Using keywords, based on facilities of every database or search engine, the most of articles that could achieve were included for final consideration. In three steps, records refined, firstly based on title and abstract we refined the records. In second step based on full text we assessed the remained articles. In final step based on quality appraisal of remained articles using CASP-critical appraisal skills program- checklists we chose rigorous articles for final analysis.

Discussion

Ionizing Radiation:

Ionizing radiation in medical imaging become one of the concise and powerful diagnostic tools in medicine, after the discovering of x-ray by Rontgen in 1985 (21-22). Nowadays about 30-50 percent of medical decisions especially in critical cases is made by radiology examinations (23). One characteristic of ionizing radiation on human body is that the energy absorbed is low but the biological effects are serious. X-ray as an ionizing radiation, despite of a lot of advantages in diagnosis and treatment of diseases, can cause serious harm to

those who exposed to (24,25). In fact, radiation is a double-edged sword that on one hand can have many benefits and, on the other hand, if it does not meet radiation safety principles, causes irreparable damage (26,27).The use of X-rays, in the form of radiography, computed tomography and nuclear medicine imaging in pregnancyis a source of real concern for the patient, her family and the clinicians(38,44).

Pregnant Women Medical Imaging:

A woman maybe become ill during pregnancy and necessitate profound medical care for her disease diagnostic, involving ionizing medical imaging; she is not more radiosensitive rather than a nonpregnant woman (45). International Commission on Radiological Protection (ICRP), reported that thousands of pregnant women are exposed to medical ionizing radiation each year (46). The risk associated with the use of X-ray imaging, which uses ionizing radiation to generate images for a pregnant woman is equal for a

nonpregnant woman of the same age. Women of child-bearing age who by their doctor prescription underwent computed tomography, nuclear medicine, angiography and some simple X-ray examinations are advised in their own interest to let physicians and radiographers know about their pregnancy (47,48). Hence the most important concern for pregnant women is fetal exposure. And the risk of ionizing radiation, depending on the stage of pregnancy and the absorbed dose, can be lead to different effects.

Effects of ionizing radiation on the fetus:

Energy deposition from ionizing radiation is the source of direct harm to body tissues. The relative susceptibility of cells, tissues, organs or organisms to the harmful effect of ionizing radiation is different. In general, it has been found that cell radio sensitivity is directly proportional to the rate of cell division and inversely proportional to the degree of cell differentiation.When a pregnant woman exposed to ionizing radiation, the biological effects on fetus is a function ofthe stage of pregnancy and the absorbed dose(50).Some of the effects of ionizing radiation on the fetus can include fetal death, microcephaly, growth retardation, impaired brain function, mental retardation and physical deformities, which occur by a high radiation dose to the undifferentiated and rapid dividing fetal cells (28,29,31,52). Ionizing radiation effects during the first week after conception, observe the rule of "all or nothing", due to the cells undifferentiability at this stage. The most sensitivity of a fetus to the radiation is seen during two to seven weeks, and in the eight to fifteen weeks after conception(46). Table 1 shows some adverse effects of ionizing radiation on the stage and period of pregnancy (28,29,31,32,34,52,60). Teratogenic, carcinogenic, or mutagenic effects as a result ofradiation directly depend on the absorbed dose of radiation exposure(51).

pregnant patients with traumatic injury:

Traumatic injuries during pregnancy has become one of the challenges of medical care in recent centuries. After the first report of the injury to the fetus caused by the firing of a gun in 1600 until now, the issue of diagnosis, management, prognosis, and outcome of a traumatic pregnant woman is a controversial problem management (35,36).A traumatic pregnant woman should be visited and evaluated typically because placental abruption can have sudden consequences for the fetus with or without signs (32,33). Management strategies of maternal trauma should be reliant on accurate assessment of the mother (41).Therefore, maternal evaluation and care should be done in an intelligent and organized manner following the general principles of trauma care in a close collaboration with perinatal specialists. (40-42). Therefore, as anatomy, physiology, and even laboratory findings change during pregnancy, clinicians should consider both mother and fetus in care and in the process of diagnosis and treatment.

According to reports, the incidence rate of trauma in pregnancy is about 5 to 7 percent (34-36). More than 50% of the trauma during pregnancy is caused by motor vehicle accidents, and about 80% of fetal deaths occur during these automobile accidents (34, 35). Because part of the traumatic injury occurs during pregnancy in the first trimester of pregnancy and is not detected in the trauma centers. Hence, these estimates are less than realistic because in most cases, pregnancy in trauma is not detected(35,36,42). A recurring dispute and disagreement between radiologists and clinicians, is a question of the appropriateness of medical imaging for a traumatic pregnancy patient. Undoubtedly, exposure to ionizing radiation is harmful and risky to any person. This is important in the case of pregnant mothers and their fetus. Consequently, radiologists tend to be cautious and hesitant about ionizing imaging techniques. This obsession is often interpreted by referring physicians to interfere into and delay in the treatment process of trauma patient. Considering the tolerable risk of fetus against the benefits of obtaining a critical diagnosis quickly for the mother, it is essential to decide on the imaging method and take diagnostic and therapeutic actions(29,39,40). Radiation doses of trauma

Table 1: effects of ionizing radiation on fetus based on the gestational age (60)

Stage	Period	Adverse effect
Pre/immediate post-implementation	From conception to 9-10 days	Lethal; survive (the rule of all or nothing)
Early organogenesis	2-6 weeks	Teratogenesis, growth retardation
Late organogenesis	12-16 weeks	Microcephaly, mental and growth retardation
Late fetal stage	From 20-25 weeks to birth	Malignancies, genetic defects

patients with diagnosis of pregnancy are typically much higher than those recommended by the American College of Obstetrics and Gynecology. Therefore, all women of childbearing age who are sent to the hospital with traumatic injuries should undergo a pregnancy test.This action maybe reduces the radiation exposure of the fetus from ionizing radiation, and partly affect the contribution of fetal mortality trauma patients which newly detected incidental pregnancy (39).

According to the above-mentioned points, it seems that nonionizing radiation like ultrasound imaging can be the first option in trauma patients, and CT scan tests should be performed if they are suspected of serious injury (29,32,33).

The fetus dose from different ionizing radiation procedures:

The risk of ionizing radiation during pregnancy is highly dependent on the absorption dose and the age of the fetus(54).Absorbed doses for different radiographic examinations are different. Depending on the type of radiography, the dosage of the embryo is also different. For example, examinations in which the embryo is placed on the pathway of the primary beam increases the received dose. On the other hand, in CT scans, the maternal and fetal doses are much higher than conventional radiography examinations (55).For embryonic age, various embryonic stages are susceptible to different risks.Embryonic risk is more significant in the period of organogenesis and embryonic development, And to a lesser extent during the second trimester, and the least risk in the last trimester (37,38,45,46). Some effects on the embryo require a minimum threshold for observing the effect (55). Table 2 shows the approximate values that can have certain biological effects on the fetus. The remarkable point is that in most CT and radiographic examinations, the embryo dose is much lower than the threshold values for biologic effects. These threshold values are extracted from the Hiroshima and Nagasaki atomic bombs survivors and animal studies data. Assessing the fetus during radiographic examination and CT scan is difficult. Because the direct measurement is not possible. Dose measurement is possible by using the tissue equivalent phantoms, and, on the other hand, it is possible to calculate it by using the Monte Carlo based simulation software and codes (56-59). Physicians should consult with expert in medical physics to estimate the fetal dose depending on the type of examination. Medical physicians are able to calculate the incidence fetal doses rapidly by using charts prepared for the various devices based on NRPB estimates, and these calculations do not require the use of computer simulations. The important point in this calculation is that these derived doses are usually obtained by considering a standard patient, which results in an inaccuracy in the obtained; because in these calculations the size of the patient is not considered.

Table 2: the approximatedose values for certain biological effects on the fetus (60)

Dose	Effects on fetus
Less than 100 mGy	A minor risk of stochastic effects
Between 100-150 mGy	Teratogenicity risk enhancement
2500 mGy	Malformation in most cases
More than 30000 mGy	Abortion

The limits of the routine doses to a conceptus from film radiography for pregnant women is about 10 mGy, and in the examination of the abdomen or pelvis, CT scan and fluoroscopy examinations are about 1 to 50 mGy depending on the examination, which can be increased in some cases(60).Table 3 shows the estimated doses of embryo in different radiology examinations. For simple radiography examinations up to a variety of CT scans from head to pelvic(40,44,45,52,62).

Table 3. the estimated doses of embryo in different radiology examinations

Examination	Fetus dose(minimum)	Fetus dose(maximum)
Plain films:		
Skull	<0.01	<0.01
Chest (two views)	0.0005	0.01
Mammogram	0.001	0.01
Abdominal (multiple views)	0.1	0.3
Lumbosacral spine	1	10
Pelvis	1.1	4
CT scans:		
Head and neck	1	10
Abdomen and pelvis	13	25
Abdomen	1.3	35
Lumbar spine (5 slices)	2.4	8.6
Pelvic	10	35
Fluoroscopic studies	<0.01	<0.01
Barium meal	1.1	5.8
Barium enema	6.8	24

Cancer risk assessment of fetus:

One of the most controversial subjects of exposure to ionizing radiation is the issue of cancer. Immediately after the discovery of ionizing radiation, many medical and industrial uses were found, and subsequently a number of effects, including cancer, were observed in those with ionizing radiation.Cancer is the inconsistency

between the cell growth and death, which is due to possible change in the DNA sequence without cell death, and is a long-term radiation effect of ionizing radiation. The risk of cancer due to exposure to ionizing radiation is a non-threshold effect, and any radiation dose can cause it, and the higher radiation doses, increases the probability of cancer risk(28).

In a society, according to the lifestyle of its people, and the level of health, there is a background rate of cancer. External cancer carcinogens usually increase the incidence of cancer rather than the background rate. The same is true for the risk of developing cancer in children. Research findings indicate that the exposure of individuals to ionizing radiation in the embryo period increases the risk of cancer. For example, it is estimated that 10mGy received dose in utero will increase the cancer risk by 0.05%.

Scientists' findings suggest that the risk of cancer in the first three to four weeks of pregnancy is much higher than in the earlier periods, and therefore radiation is more important in this period(63,64,). The primary results from these studies have shown that a dose about 25 mGy for a fetus is estimated to increase the rate of background childhood cancer by twofold.

Researchers use risk coefficients to estimate the risk of ionizing radiation for irradiated embryos. These coefficients are calculated for the embryo received dose that is obtained by the methods mentioned in the previous sections, and these coefficients are normalized to oneGy(65). Based on these coefficients, the probability of hereditary effects in future generations is $2.4*10^{-2}$ per one Gy of received dose. The risk of fatal childhood cancer caused by fetal exposure is estimated to be around $3.0 * 10^{-2}$ per Gyat the ages of less than 15 years (66). the Increased genetic risk for an exposed embryo rather thannon-exposed embryos is around $2*10^{-3}$from high-dose radiology examinations, which is small in comparison to the risk of background risk of genetic disease (38,56,66).

Nonionizing Radiation imaging:

Considering the harmful effects of ionizing radiation in imaging traumatic patients with a large number of images. There is also a danger to the pregnant women and her fetus. Therefore, as far as possible, it is necessary to seek the administration of non-ionizing imaging methods for pregnant women, especially traumatic pregnant women. Non-ionizing imaging techniques include imaging techniques such as MRI and ultrasonography. The interaction of these radiations with a tissue is different from the interactions of ionizing radiation with tissue and cannot create ionization. Often, these interactions with the irradiated tissue is through the heat generation in the tissue.

Exposure to non-ionizing radiation by pregnant women can also give the fetus some radiation. Does this radiation on the embryo produce a significant and persistent harmful effect? The answer to this question seems clear. Many researchers have been investigated on this topic. The effects of non-ionizing radiation on the embryo have been widely studied and no significant risks have been observed(51,67).Among various types of non-ionizing radiation,low-frequency electromagnetic fields are somewhat controversial issue. There is pooled epidemiological evidence that prenatal exposure to low frequency electromagnetic fields can lead to leukemia in childhood. For this reason, the issue of fetal radiation from low frequency electromagnetic fields is of especial concern (70).In total, studies in this regard did not reveal a relationship between exposure to embryonic fetuses with electromagnetic fields and postpartum problems, such as birth defects, abortions or childhood leukemia (69-67-69).

In the case of ultrasound imaging, studies have not reported any signs of adverse effects after fetal irradiation. Due to the thermal and non-thermal effects of ultrasound, it should be made done to pregnant women only when medically indicated (71,72). MRI is another non-ionizing imaging method used during pregnancy. Studies on children who have exposed during the embryonic to 1.5 Tesla have shown no side effect until the age of nine (73,74).

Conclusions

A lot of ionization imaging is done for trauma patients. Due to the risks of ionizing radiation, these methods should be carefully and obsessively monitored. Another concern for patient radiation is traumatic pregnant women, not only there is a hazard risk to themselves, the fetus is also exposed to radiation and is associated with risks. Concerns about radiographic examinations in the abdomen and pelvic area, or near these areas, are higher due to the fact that the fetus is directly exposed to radiation. For women who injured from multiple trauma a diagnostic procedure prescribed by the medical team is necessary to save the mother and the fetus.

Therefore, the image should be done to save the patient. If the imaging does not take place, the diagnosis may not be appropriate and the lack of treatment will threaten the pregnant woman and

the fetus. Therefore, the risk to mother and fetus that it is not detected correctly is greater than the risk of radiation ionizing radiation.

As a general conclusion, the examinations that include the abdominal and pelvic region should be justified in detail. And, as far as possible, use non-ionizing imaging techniques instead of ionizing methods.One of the most reliable methods for reducing fetal doses is the development and promotion of non-ionizing imaging methods in traumatic pregnant women, such as ultrasound and MRI. However, in cases where ionizing imaging techniques involve providing important clinical information, it should not be withheld due to ionizing radiation concerns. However, all efforts should be made on the pregnant women in such a way that the embryo dose is as low as possible. It is strongly recommended that physician and medical team staff have a good knowledge and attitudes towards the radiation protection principles and in practice use standard of radiation protection safety principles.

Acknowledgements

The authors would like to thank the Vice Chancellor for Research of Birjand University of medical sciences for their support.

Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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