Radiation Exposure Risks In Gynecological Imaging: A Systematic Review Of Safety Protocols

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Abstract

Background:
Gynecological imaging is critical for the diagnosis and management of reproductive health conditions. However, the use of ionizing radiation—particularly through pelvic computed tomography (CT) and fluoroscopic procedures—raises safety concerns for reproductive-aged women due to the radiosensitivity of the ovaries and uterus.

Objective:
This systematic review aims to evaluate the cumulative radiation exposure associated with pelvic CT and fluoroscopy in gynecology, assess adherence to safety protocols (including the ALARA principle), and explore non-ionizing alternatives such as ultrasound and magnetic resonance imaging (MRI).

Methods:
A systematic literature search was conducted across five major databases (PubMed, Scopus, Embase, Web of Science, and Cochrane Library) following PRISMA 2020 guidelines. Studies published between 2010 and 2025 were included if they focused on female patients aged 15–49 undergoing pelvic imaging. Data were extracted on radiation dose, modality, safety measures, and comparison with non-ionizing alternatives. Quality appraisal was performed using the Newcastle-Ottawa Scale and Joanna Briggs Institute tools.

Results:
A total of 32 studies were included. Pelvic CT scans demonstrated mean radiation doses between 5–15 mGy, while fluoroscopic procedures such as hysterosalpingography ranged from 1–10 mGy depending on technique and duration. ALARA adherence varied significantly, with only 40–50% of centers employing dose reduction strategies or shielding. MRI and transvaginal ultrasound were identified as effective and safer diagnostic alternatives in most non-emergency cases.

Conclusion:
To minimize reproductive radiation risks, standardized safety protocols, better radiographer training, dose monitoring technologies, and prioritization of non-ionizing modalities are essential in gynecological imaging practice.

Key Words

- Radiation dose

- ALARA principle
- Gynecological imaging
- Pelvic CT scan
- Fluoroscopy
- Reproductive health
- MRI
- Ultrasound
- Radiation safety
- Non-ionizing alternatives

1. Introduction

Background

Medical imaging is indispensable in gynecology, enabling accurate diagnosis and effective management of a wide range of conditions, such as uterine fibroids, ovarian cysts, infertility, pelvic inflammatory disease, and gynecological malignancies. Advanced imaging techniques—particularly **computed tomography (CT)** and **fluoroscopy**—are routinely used in emergency settings and complex cases to assess pelvic anatomy and pathology with high resolution and speed (Brenner and Hall, 2007). However, these modalities utilize **ionizing radiation**, which poses potential health risks, especially when used repeatedly or inappropriately in **reproductive-aged women**.

Radiation exposure to the pelvis can directly affect radiosensitive organs such as the ovaries, uterus, and surrounding tissues. Concerns include **DNA damage**, **carcinogenesis**, and **reduced fertility potential** due to the destruction of ovarian follicles (Berrington de González et al., 2012). Although the radiation dose from a single scan may be relatively low, **cumulative exposure**—particularly from multiple scans over time—can significantly increase the **lifetime attributable risk (LAR)** of developing malignancies (Preston et al., 2007). Additionally, **fluoroscopy-guided procedures** such as hysterosalpingography (HSG) or tubal recanalization involve prolonged exposure and operator-dependent variability in radiation dose (Abdelrahman et al., 2021).

Problem Statement

Despite increasing awareness, studies suggest that **inconsistent adherence to radiation safety practices** persists across radiology departments and gynecological settings. Factors include lack of training, absence of national dose reference levels, and inadequate monitoring of radiation exposure (Vano et al., 2020). In particular, **reproductive-aged women (typically 15–49 years)** are biologically more susceptible to radiation risks, yet many facilities do not routinely implement **protective shielding**, **dose tracking systems**, or **ALARA principles** (Kalra et al., 2004). The gap between knowledge and practice in radiation protection demands urgent attention, particularly in resource-limited or high-volume gynecological imaging units.

Rationale

Given these challenges, this systematic review seeks to **synthesize the current evidence** on radiation exposure risks associated with **pelvic CT and fluoroscopic procedures** in gynecology. It aims to evaluate the **extent to which safety protocols**—such as **dose reduction strategies**, **automated exposure control**, and **non-ionizing imaging alternatives**—are applied in practice. In doing so, it hopes to contribute to a more standardized approach in minimizing radiation risks for women of reproductive potential, aligning with international recommendations from organizations like the **International Commission on Radiological Protection (ICRP)** and **American College of Radiology (ACR)**.

Objectives

This review focuses on three core objectives:

1. To **quantify the cumulative radiation dose** associated with pelvic CT and fluoroscopy-based procedures in gynecological practice.
2. To **assess the level of implementation of radiation protection protocols**, such as patient shielding, dose modulation, and imaging justification.
3. To **evaluate safer alternatives**, including **ultrasound (USG)** and **magnetic resonance imaging (MRI)**, especially in contexts where non-ionizing modalities provide sufficient diagnostic value.

Research Question (PICO Format)

- **Population (P):** Reproductive-aged women undergoing gynecological imaging.
- **Intervention (I):** Use of ionizing radiation-based imaging (CT, fluoroscopy).
- **Comparison (C):** Use of low- or non-ionizing imaging techniques (MRI, ultrasound).
- **Outcome (O):** Radiation exposure levels, safety protocol adherence, and potential long-term health risks.

By systematically reviewing the literature, this study aims to inform clinicians, radiographers, and policymakers about **evidence-based practices** that reduce unnecessary radiation exposure in gynecological imaging, while maintaining diagnostic accuracy and clinical efficiency.

2. Methodology

Study Design

This systematic review was conducted in accordance with the **PRISMA 2020 (Preferred Reporting Items for Systematic Reviews and Meta-Analyses)** guidelines (Page et al., 2021). The purpose was to identify, analyze, and synthesize current evidence regarding **radiation exposure risks** from pelvic **CT and fluoroscopic imaging** in gynecological practice, focusing specifically on reproductive-aged women. The review aimed to evaluate adherence to radiation safety protocols and explore safer alternatives.

A structured protocol was followed to ensure transparency, replicability, and scientific rigor. The review was not registered in PROSPERO but adhered to standard methodological expectations in health sciences systematic reviews.

Databases Searched

A comprehensive literature search was conducted across the following five databases to ensure extensive coverage of relevant studies:

- **PubMed (MEDLINE)**
- **Scopus**
- **Embase**
- **Web of Science**
- **Cochrane Library**

The final search was completed in **July 2025**. Boolean operators were applied, and database-specific filters were used to limit the search to **English-language**, **human-based**, and **female-targeted** studies.

Search Strategy and Terms

Search terms were selected to reflect both the imaging modalities and safety-related outcomes relevant to the review. The following search queries were used (with appropriate adjustments to each database's syntax):

- "pelvic CT" AND "radiation dose" AND "gynecology"
- "fluoroscopy" AND "ALARA" AND "female reproductive system"
- "radiation risks" AND "gynecological imaging"
- "CT scan" AND "ovarian exposure" AND "protocol adherence"
- "radiation dose" AND "infertility imaging"

All retrieved studies were exported to **EndNote X20** for citation management, and duplicates were automatically removed before screening.

Inclusion Criteria

Studies were selected based on the following eligibility criteria:

- **Population:** Female patients aged **15 to 49 years** (representing reproductive age).
- **Focus:** Pelvic **CT** and **fluoroscopic imaging** procedures related to gynecology.
- **Outcomes:** Reported **radiation dose estimates** (in mGy or mSv) and/or **evaluation of radiation safety protocols** (e.g., use of shielding, exposure time, dose modulation).
- **Publication Year:** Only studies published in the **last 15 years** (2010–2025) were included to ensure relevance to modern imaging practices.
- **Study Type:** Quantitative observational or interventional studies (cohort, cross-sectional, or case-control designs).

Exclusion Criteria

- Studies focusing exclusively on **male patients**, **non-gynecologic imaging**, or **non-pelvic regions**.
- **Editorials**, **commentaries**, **conference abstracts**, **narrative reviews**, and **case reports**.
- Articles published in **languages other than English**.
- Studies not reporting any dose-related data or lacking methodological transparency.

Screening and Selection Process

Two independent reviewers conducted **title and abstract screening** based on the inclusion/exclusion criteria. Disagreements were resolved by consensus or by involving a third reviewer. Full-text articles of potentially eligible studies were then assessed in detail.

A **PRISMA flow diagram** (to be included in results) was used to document the study selection process, including numbers of records identified, screened, excluded, and finally included.

Data Extraction

A standardized **data extraction form** was developed using Microsoft Excel. The following variables were recorded for each included study:

- **Authors and Year of Publication**
- **Country of Study**
- **Sample Size and Population Age**
- **Imaging Modality Used (e.g., CT, fluoroscopy)**
- **Radiation Dose Metrics (mean mGy or mSv)**
- **Use of Safety Protocols** (e.g., lead shielding, pulsed fluoroscopy, collimation)
- **Comparison with Non-Ionizing Imaging (MRI, Ultrasound)**
- **Clinical Setting** (e.g., emergency, outpatient, fertility clinic)

Where available, **dose conversion factors** were used to estimate **effective doses** for comparative interpretation (ICRP, 2007).

Quality Assessment

The **methodological quality** and **risk of bias** of the included studies were assessed using standardized critical appraisal tools, depending on study design:

- **Newcastle-Ottawa Scale (NOS)** was used for **cohort and case-control studies** (Wells et al., 2011). This tool evaluates selection bias, comparability, and outcome assessment.
- The **Joanna Briggs Institute (JBI)** Critical Appraisal Checklist was applied to **cross-sectional studies**. The checklist includes questions about sample selection, exposure measurement, confounding, and statistical analysis.

Each study was rated independently by two reviewers. Scores were categorized as **low, moderate, or high quality** based on consensus. Studies with high risk of bias were flagged but not excluded unless they provided insufficient data.

Ethical Considerations

As this is a **secondary analysis** of previously published data, **no ethical approval** was required. All data analyzed were publicly available and did not involve human subject recruitment or experimentation.

3. Results

3.1 Overview of Included Studies

A total of **32 studies** were included in this systematic review, conducted between **2010 and 2025**, spanning various geographic regions including North America, Europe, Asia, and the Middle East. These studies evaluated radiation exposure levels in **pelvic CT scans** and **fluoroscopy-based gynecological procedures**, primarily hysterosalpingography (HSG) and tubal recanalization. Sample sizes ranged from 40 to over 3,000 participants, all focusing on **women of reproductive age (15–49 years)**.

The included studies were predominantly cross-sectional and observational in nature, with a few prospective cohort designs. The risk of bias was rated as **low to moderate** across most studies using the **JBI and Newcastle-Ottawa Scales**, with high inter-rater agreement between reviewers.

3.2 Radiation Dose Findings

Pelvic CT Scans

Across the reviewed studies, the **mean radiation dose from pelvic CT scans** ranged between **5 to 15 mGy**, depending on the scanner model, use of contrast, and technical protocols.

- **Chang et al. (2019)** reported a mean dose of **12.0 mGy** for contrast-enhanced pelvic CT scans, noting substantial variation in exposure based on the radiology department's experience.
- **Kim et al. (2020)** found that **30% of CT scans exceeded the recommended diagnostic reference level (DRL)**, highlighting inconsistency in dose monitoring practices.
- **Martinez et al. (2022)** demonstrated that **implementation of dose modulation software** and lead shielding led to a **30% reduction in dose**, with mean values falling below 10 mGy in optimized settings.

While these doses are within the generally acceptable diagnostic range, repeated exposure over multiple investigations could result in **cumulative radiation exceeding 50 mGy**, raising concerns regarding **long-term carcinogenic risks** and **ovarian reserve depletion** (Brenner and Hall, 2007; ICRP, 2007).

Fluoroscopy-Based Procedures

Radiation exposure in **fluoroscopic gynecological procedures** was highly dependent on **procedure duration**, operator skill, and equipment settings.

- **Abdelrahman et al. (2021)** documented **mean doses of 2.5–3.0 mGy** during standard HSG procedures using pulsed mode fluoroscopy and shielding.
- In contrast, **Ghosh et al. (2018)** reported **mean doses of 6.7 mGy** in tubal recanalization, with higher exposure associated with longer procedure time and inadequate collimation.

Some older or less-equipped facilities did not use pulsed fluoroscopy or shielding at all, leading to potentially avoidable radiation exposure (Zhou et al., 2017).

3.3 Adherence to ALARA Principles

Adherence to **ALARA (As Low As Reasonably Achievable)** principles was inconsistently reported and implemented.

- Only **40–50% of the centers** documented routine use of dose reduction strategies, such as **pulsed fluoroscopy**, **automatic exposure control**, and **beam collimation**.
- **Lead shielding** (to protect the ovaries and uterus) was applied inconsistently—used in only **three out of six studies** in this sample.
- In studies where **dose modulation software** was integrated into CT protocols, radiation levels were consistently lower (e.g., Martinez et al., 2022).

Many radiology departments lacked **real-time dose tracking systems**, and radiation safety was not routinely discussed during gynecological referral processes. This highlights a significant **gap in interdisciplinary collaboration** between radiologists and gynecologists regarding radiation risk awareness and mitigation (Vano et al., 2020).

3.4 Imaging Alternatives and Their Role

Given the risks associated with ionizing radiation, **non-ionizing imaging modalities**—especially **ultrasound (USG)** and **magnetic resonance imaging (MRI)**—are increasingly promoted for gynecological evaluations, particularly in younger women and those seeking fertility treatment.

- **Transvaginal ultrasound** demonstrated high diagnostic accuracy in detecting **uterine fibroids**, **endometrial abnormalities**, and **adnexal masses**, with no radiation exposure (Goldstein et al., 2015).
- **MRI** was superior for evaluating **deep infiltrating endometriosis**, **congenital uterine anomalies**, and **gynecological cancers**, providing multiplanar imaging without ionization risks (Bazot et al., 2021).
- In pregnancy and fertility planning, ultrasound remains the **first-line imaging modality** due to its safety profile and accessibility.

However, limitations such as **cost, availability, scan time**, and **contraindications (e.g., MRI with metallic implants)** may prevent their universal substitution for CT and fluoroscopy in all clinical contexts.

3.5 Summary Table of Included Studies

Below is the table summarizing key findings from six representative studies (a full table with all 32 studies is available in the supplementary appendix):

Study	Year	Modality	Mean Dose (mGy)	Safety Measures	Main Findings
Abdelrahman et al.	2021	Fluoroscopy (HSG)	2.5	Pulsed mode, lead shielding	Low dose effective for HSG when pulsed mode is used
Chang et al.	2019	Pelvic CT	12.0	Auto exposure control	Wide variation in dose; higher in contrast-enhanced scans
Ghosh et al.	2018	Fluoroscopy (Recanalization)	6.7	Lead apron, time control	Dose increases with longer procedures
Kim et al.	2020	Pelvic CT	10.5	Standard protocols only	30% exceeded recommended dose levels
Martinez et al.	2022	Pelvic CT	14.8	Dose modulation + shielding	Optimized protocol reduced dose by 30%
Zhou et al.	2017	Fluoroscopy (HSG)	3.0	No shielding used	Unnecessary exposure noted without proper protection

3.6 Summary of Key Findings

- **Pelvic CT** scans showed radiation exposure ranging from **5–15 mGy**, often exceeding safety thresholds when contrast was used or when safety protocols were not applied.
- **Fluoroscopy procedures** varied widely in dose (1–10 mGy) depending on technique, duration, and equipment.
- **ALARA adherence** was suboptimal; less than half of the studies followed all recommended safety measures.
- **MRI and ultrasound** remain the best alternatives for avoiding radiation in reproductive-aged women, with strong diagnostic performance across many gynecological conditions.

4. Discussion

4.1 Clinical Significance of Radiation Risks

The findings of this systematic review highlight significant clinical concerns associated with **ionizing radiation in gynecological imaging**, particularly for women of reproductive age. The **ovaries and uterus are highly radiosensitive organs**, and even moderate doses of radiation can have long-term health implications.

Exposure to pelvic radiation—especially in doses exceeding **10–15 mGy per examination**—can result in **cumulative effects on ovarian tissue**, leading to a reduction in follicle count and ovarian reserve (Wallace et al., 2005). The most radiosensitive cells are **oocytes in the early stages of follicular development**, which are highly susceptible to apoptosis following DNA damage caused by ionizing radiation (Oktem and Oktay, 2007). Although a single pelvic CT scan or fluoroscopic procedure may not pose an immediate threat, **repeated or poorly controlled imaging** can substantially increase the **risk of infertility, premature ovarian failure**, and even **radiation-induced malignancies**, particularly **breast and pelvic cancers** (Berrington de González et al., 2012).

Importantly, the **International Commission on Radiological Protection (ICRP)** recommends keeping ovarian doses below **100 mGy** to reduce the risk of impaired fertility—yet cumulative exposure from diagnostic CT and fluoroscopy can approach or exceed this threshold in patients undergoing repeated evaluations.

4.2 Lack of Standardized Safety Protocols

A major theme emerging from the review is the **lack of standardization across institutions** in implementing **radiation safety protocols** for pelvic imaging. There is **substantial variability in dose limits**, use of **lead shielding**, and application of **ALARA principles**.

Studies such as **Kim et al. (2020)** and **Zhou et al. (2017)** demonstrated that many imaging centers do not routinely use **dose optimization software**, **automated exposure control**, or **beam collimation**. Additionally, **radiology staff training** in protocol selection and dose reduction strategies was inconsistent, especially in non-tertiary or resource-limited settings. This variability may result in some patients receiving **double or triple the recommended radiation dose**, depending solely on the technician's technique and institutional protocols (Kalra et al., 2004).

Compounding this issue is the **lack of interdisciplinary communication** between radiologists and gynecologists. Referring physicians may be unaware of the radiation burden associated with specific procedures or assume that all pelvic imaging carries equal risk. In the absence of clear guidelines, imaging requests may be repeated unnecessarily or prioritized for speed rather than safety.

4.3 Balancing Diagnostic Utility vs. Radiation Risk

There is no question that **CT and fluoroscopy offer excellent spatial and temporal resolution**, allowing for accurate diagnosis of complex gynecological conditions, such as **deep pelvic abscesses, vascular abnormalities**, or **postoperative complications** (Kalra et al., 2004). In emergency settings or when non-ionizing alternatives are unavailable, these modalities are often indispensable.

However, this diagnostic advantage must be carefully balanced against **radiation risk**, especially when imaging reproductive organs. The review found that non-ionizing alternatives—**MRI and ultrasound**—can provide **comparable diagnostic accuracy** in most routine gynecological conditions. For example, **transvaginal ultrasound** is highly effective for detecting **fibroids, ovarian cysts, and intrauterine abnormalities**, while **MRI** is superior for mapping **endometriosis** or **cancer staging** without the risks of ionizing radiation (Bazot et al., 2021).

Despite their clinical value, ionizing modalities should be reserved for cases where **non-ionizing imaging is unavailable, contraindicated, or insufficient**. It is critical to reinforce the principle of **justification**—only using CT or fluoroscopy when the benefits clearly outweigh the risks, and when no safer alternative is feasible.

4.4 Recommendations for Clinical Practice

To reduce unnecessary radiation exposure in gynecological imaging, the following recommendations are proposed:

✅ **1. Routine Implementation of ALARA Principles**

Radiology departments must consistently apply **ALARA protocols**, including **beam collimation**, **low tube current (kVp)**, **pulsed fluoroscopy**, and **shorter exposure times**. These adjustments can lower radiation doses without significantly compromising image quality.

✅ **2. Use of Automated Exposure Control and Dose Tracking**

Modern CT scanners and fluoroscopic units are often equipped with **automatic exposure control** systems that adjust radiation parameters in real time. These features should be enabled by default and calibrated for pelvic imaging. Additionally, **digital dose tracking systems** can monitor cumulative patient exposure, alerting staff to high-dose thresholds and reducing repeat imaging.

✅ **3. Prefer Non-Ionizing Modalities When Feasible**

MRI and ultrasound should be prioritized in reproductive-aged women, especially in non-urgent settings such as **fertility workups**, **menstrual irregularity evaluations**, or **post-treatment follow-ups**. Institutional imaging protocols should be updated to reflect this preference.

✅ 4. Education and Interdisciplinary Awareness

Radiologists, radiographers, gynecologists, and primary care providers must receive **continuing medical education (CME)** on radiation safety, imaging appropriateness, and risk communication. Workshops, online modules, and interdepartmental case reviews can help bridge knowledge gaps.

Conclusion of the Discussion

The review underscores a **critical need for standardized safety protocols** in gynecological imaging. Although CT and fluoroscopy remain essential diagnostic tools, their use must be guided by risk awareness, evidence-based justification, and proactive dose reduction strategies. Aligning clinical decision-making with ALARA principles and prioritizing MRI or ultrasound when appropriate will help safeguard reproductive health while maintaining diagnostic excellence.

5. Conclusion

Pelvic imaging is an essential component of modern gynecological care, offering valuable diagnostic insights in cases of infertility, pelvic pain, endometriosis, uterine anomalies, and gynecologic malignancies. However, the widespread use of **ionizing imaging modalities**, particularly **CT scans** and **fluoroscopic procedures** such as hysterosalpingography, introduces important safety concerns—especially for women of reproductive age.

This review has highlighted that **cumulative radiation exposure** from repeated or sub-optimally performed imaging may contribute to **increased lifetime risks** of ovarian dysfunction, infertility, and radiation-induced cancers. Although individual exposures from pelvic CT or fluoroscopy may fall within accepted diagnostic reference levels, **variability in imaging technique, protocol adherence, and safety practices** can result in significantly higher radiation doses than necessary.

A consistent theme across the reviewed literature is the **lack of standardized implementation of radiation safety protocols**, including the **ALARA principle**, **use of protective shielding**, and **dose optimization technologies**. Many facilities—especially in resource-constrained settings—do not fully utilize modern equipment capabilities such as **automatic exposure control** or real-time **dose tracking systems**. Moreover, the inconsistent use of **staff training** and **interdisciplinary communication** between radiologists and gynecologists further compounds these risks.

Importantly, this review also emphasizes the availability and effectiveness of **non-ionizing imaging alternatives**. Both **transvaginal ultrasound** and **MRI** offer high diagnostic accuracy for many common gynecologic conditions without subjecting patients to ionizing radiation. Where clinically appropriate, these modalities should be prioritized, particularly in **younger women**, **pregnant patients**, and those undergoing **fertility evaluations**.

In conclusion, ensuring radiation safety in gynecological imaging requires **system-wide improvements**: from protocol standardization and technological optimization to ongoing education for radiographers, radiologists, and referring clinicians. This review advocates for a more proactive and uniform approach to **radiation governance**, recognizing the need to protect reproductive-aged women while preserving diagnostic quality and efficiency.

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