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A medical physics review of the use of contrasodium in hysterosalpingography (HSG) examinations

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ABSTRACT

Hysterosalpingography (HSG) is a widely used radiological procedure for evaluating female infertility, particularly in assessing fallopian tube patency and uterine anatomy. A critical component of HSG is the use of contrast media. Water-based contrast agents, such as contrasodium, are often preferred due to their favorable safety profile. The field of medical physics plays a vital role in ensuring diagnostic image quality while minimizing biological risks from radiation exposure. This article reviews the effectiveness of contrasodium in HSG procedures from a medical physics perspective, comparing it to other contrast agents and examining radiation dose management in women of reproductive age. The study is a literature review of scientific publications from the past decade (2015–2024), including clinical trials, meta-analyses, and international guidelines from the WHO and ICRP. The analysis focuses on imaging physics parameters, contrast efficiency, biological safety, and radiation dose evaluation. Findings indicate that contrasodium provides sufficient radiological imaging with minimal biological risk. Although oil-based contrast agents are associated with higher post-HSG pregnancy rates, they pose greater risks of adverse biological effects. Medical physicists are instrumental in optimizing imaging protocols, managing radiation doses, and selecting exposure parameters in accordance with the ALARA (As Low As Reasonably Achievable) principle. In conclusion, the use of contrasodium in HSG offers an optimal balance between diagnostic efficacy and patient safety. The standardization of evidence-based HSG protocols at the national level is recommended to enhance clinical practice in Indonesia.

Keywords: Hysterosalpingography; contrast sodium; medical physics; radiation dose; female infertility

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INTRODUCTION

Hysterosalpingography (HSG) is a conventional radiological imaging procedure widely used to evaluate uterine morphology and fallopian tube patency, particularly in women experiencing infertility [1]. In this procedure, a contrast agent is injected into the uterine cavity through a cervical cannula, and its flow is monitored using X-ray-based fluoroscopy. One of the commonly used contrast agents in HSG is contrasodium, a water-soluble iodine-based compound such as sodium diatrizoate or a mixture with meglumine diatrizoate. These agents are radiopaque due to their high atomic number, allowing significant X-ray absorption and producing a clear contrast between the uterine/tubal cavity and surrounding tissues [2]. Compared to oil-based contrast agents, contrasodium offers advantages in terms of biological safety and rapid clearance from the body.

From a medical physics perspective, the use of contrasodium in HSG involves several key considerations, including the interaction of ionizing radiation with matter, the X-ray absorption characteristics of iodine, and the optimization of exposure parameters to achieve high-quality imaging at the lowest reasonable radiation dose [3]. In this context, sodium-based contrast media—typically low-osmolar and non-ionic—are preferred due to their ability to produce excellent imaging quality with a lower incidence of adverse reactions [4]. A recent meta-analysis reported that oil-based contrast agents are associated with higher post-HSG pregnancy rates, with an odds ratio of 1.51 (95% CI 1.23 – 1.86; $p < .0001$), but also with a higher incidence of intravasation compared to water-based agents ($OR = 2.09$; $p = .03$) [5].

From a safety standpoint, meta-analyses show an intravasation incidence of 2.7% (95% CI 1.7 – 3.8) for oil-based media, with four cases of serious embolism (retinal/cerebral), albeit with no fatalities, while water-based media exhibit an incidence of 2.0% (95% CI 1.2 – 3.0) [4]. A national Dutch survey (2017) involving 5,165 HSG procedures reported an intravasation rate of 4.8% with oil-based agents versus 1.3% with water-based agents, with no cases of embolism or mortality [6].

In terms of radiation dose, a Nigerian study (2020) recorded average entrance surface doses (ESD) ranging from 15 – 34 mGy and effective doses between 1.2 – 2.5 mSv [7]. In Sudan (2015), ESD ranged from 13.6–35.7 mGy, with effective doses between 1.6 – 4.3 mSv, highlighting considerable variation across facilities [8]. The implementation of digital fluoroscopy has been shown to reduce patient doses by up to threefold compared to conventional techniques [3].

Additionally, physical parameters such as tube voltage (kV), tube current (mAs), pulse mode, and the use of automatic exposure control (AEC) systems contribute to reducing radiation doses while maintaining diagnostic image quality [7].

This review aims to summarize the interaction between medical physics aspects (such as X-ray–contrasodium dynamics and dose optimization) and clinical outcomes (diagnostic effectiveness and safety) in HSG procedures over the past decade, in support of evidence-based practice in reproductive radiology.

As imaging technologies advance and awareness of patient safety increases, medical physics–based evaluations of contrast agent utilization in HSG have become increasingly relevant. This article reviews the fundamental physical and radiological characteristics of contrasodium, its influence on image quality, and radiation protection considerations.

THEORITICAL BACKGROUND

Basic Principles of X-Ray Imaging in Diagnostic Radiology

X-ray imaging is based on the differential absorption of radiation by various body tissues. As an X-ray beam passes through the patient's body, part of the radiation is absorbed (absorption) while the remainder is transmitted. These differences result in contrast variations that form diagnostic images captured by a digital detector or film [9]. X-ray absorption is influenced by several factors:

a) **X-ray energy (kVp)**: Higher energy results in lower image contrast but greater tissue penetration.
b) **Effective atomic number (Z)**: Materials with high Z, such as iodine ($Z = 53$), absorb X-rays more effectively than soft tissue ($Z \approx 7$).
c) **Tissue density and thickness**: Within the diagnostic energy range (30 – 120 keV), the dominant interactions are the photoelectric effect and Compton scattering. The photoelectric effect, which is more prevalent in high-Z materials, significantly contributes to image contrast [3].

Radiopaque Contrast Agents: Physical Properties of Contrasodium

Contrasodium is a water-soluble iodine-based contrast agent, commonly composed of sodium and/or meglumine diatrizoate. It enhances contrast by increasing the X-ray absorption difference between contrast-filled body cavities and surrounding tissues [10, 11]. Key physical properties of contrasodium include:

a) **High atomic number (iodine)**: Enhances X-ray absorption via the photoelectric effect.
b) **High osmolality**: May affect patient comfort but facilitates rapid excretion.
c) **Moderate viscosity**: Enables easier injection and distribution within the uterine and tubal cavities.

The use of contrasodium allows for sharp visualization of uterine and tubal anatomy without the prolonged inflammation risk associated with oil-based contrast agents.

Physical Parameters in HSG

Optimizing HSG imaging requires appropriate adjustment of technical parameters, including:

a) **kVp and mAs**: X-ray energy must adequately penetrate the pelvic region, typically between 70 – 90 kVp.
b) **Exposure time**: Should be as brief as possible to minimize motion artifacts and reduce radiation dose.
c) **Collimation and grid use**: Helps limit the imaging field and enhance image quality.

Additionally, calculating dose-area product (DAP) and estimating mean ovarian dose are critical to ensuring patient safety, particularly because female reproductive organs are highly sensitive to ionizing radiation [12].

The Role of Medical Physics in Diagnostic Radiology

Medical physics plays a central role in:

a) Calibrating and performing quality control on fluoroscopic equipment.
b) Adjusting imaging parameters in line with the ALARA (As Low As Reasonably Achievable) principle.
c) Estimating and reporting patient radiation dose.
d) Evaluating image quality (contrast-to-noise ratio, signal-to-noise ratio).
e) Educating medical personnel on radiation protection and imaging safety protocols.

In the context of HSG, medical physicists are involved in equipment quality assurance, biological risk analysis, and the optimization of procedural protocols to ensure both diagnostic efficacy and patient safety.

USE OF CONTRASODIUM IN HYSTEROSALPINGOGRAPHY (HSG)

Principles of HSG Examination

Hysterosalpingography (HSG) is a diagnostic radiological procedure performed to assess the morphology of the uterine cavity and the patency of the fallopian tubes, especially in the evaluation of female infertility. The procedure involves injecting a contrast agent into the uterine cavity via a cervical cannula, followed by real-time X-ray fluoroscopic imaging. The contrast medium fills the uterus and, if the fallopian tubes are unobstructed, flows into the peritoneal cavity, which can then be visualized [12].

The HSG procedure involves two primary components: (1) a contrast medium—either water-or oil-based, and (2) an X-ray imaging system, typically in fluoroscopy mode. The contrast medium allows visualization of the tubal lumen and uterine cavity due to its high atomic number and density, which significantly absorb X-rays compared to surrounding tissues [13].

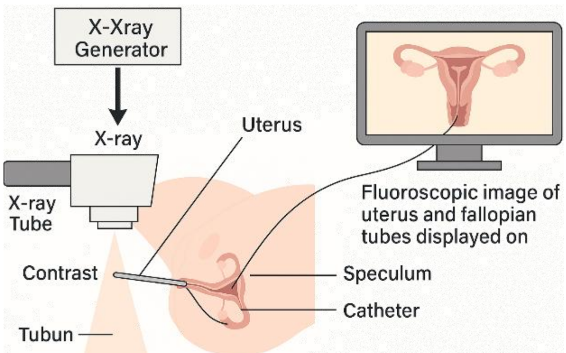

Figure 1. Principle of HSG examination.

Characteristics of Contrasodium

Contrasodium refers to iodinated, water-soluble contrast media such as Iopromide, Ioxaglate, or Iohexol. These agents are generally non-ionic and low-osmolar, designed to minimize the risk of allergic reactions and intravasation. Key physical properties of contrasodium include:

a) **High atomic number (Z = 53 for iodine)** → enhances X-ray contrast.
b) **High optical density** → improves lumen delineation.
c) **Low osmolality** → reduces the risk of pain and tissue irritation [9].

Comparatively, oil-based contrast agents (e.g., Lipiodol) are more viscous and provide longer-lasting contrast but carry higher risks of embolism and adverse effects if intravasation occurs [3].

Key Characteristics of Contrasodium:

a) **Water-soluble**: Easily mixes with bodily fluids and is rapidly excreted.
b) **Radiopaque**: Contains iodine (Z = 53), which efficiently absorbs X-rays, providing clear contrast between the uterine/tubal lumen and surrounding tissues.
c) **High osmolality**: Enhances X-ray absorption but may also cause temporary discomfort or cramping shortly after injection [10].
d) **Low to moderate viscosity**: Facilitates easy injection and uniform distribution throughout the uterine cavity and fallopian tubes.

X-Ray Interactions with Contrast Media and Tissues

In medical physics, the absorption of X-rays by materials is governed by the photoelectric effect and Compton scattering. The photoelectric effect dominates at lower X-ray energies (< 50 keV) and increases exponentially with the atomic number (Z^3), while inversely related to X-ray energy (E^3) [3, 14].

Table 1. Comparison of physical properties of contrast media in HSG.

Parameter	Water-based contrasodium	Oil-based contrasodium
Type	Non-ionic, low-osmolar	Ionic, high-viscosity
Viscosity	Low	High
Duration of visualization	Short (≤ 5 minutes)	Long (up to 30 minutes)
Risk of allergic reaction	Low	Moderate
Risk of intravasation	Lower	Higher
Pregnancy effectiveness (OR)	1.0 [15]	1.51 [15]
Serious adverse effects	Very rare	Possible lipid embolism

Iodinated contrast media (high-Z) induce significantly more photoelectric interactions than soft tissues (low-Z), creating strong intensity differences on radiographic images. This explains the high efficacy of contrasodium in visualizing reproductive tract lumens during HSG.

A high atomic number (Z) enhances the photoelectric effect, resulting in brighter and clearer imaging. Therefore, contrasodium is highly effective in distinguishing the lumen from surrounding tissues during hysterosalpingography (HSG).

Table 2. X-ray interactions with tissues and contrast media.

Material	Effective atomic number (Z)	Dominant interaction (< 50 keV)	Radiographic appearance
Soft tissue (muscle, fat)	~ 7 – 8	Compton scattering	Low absorption
Bone	~ 13 – 14	Photoelectric & Compton	Moderate contrast
Contrasodium (iodine, Z = 53)	~53	Predominantly photoelectric	High absorption → bright white area

Advantages and Limitations of Contrasodium

Advantages:

a) High-contrast imaging under fluoroscopy.
b) Lower infection risk compared to oil-based contrast.
c) Rapid elimination from the body, making it suitable for hypersensitive patients

Limitations:

a) High osmolality may cause transient cramping or discomfort during injection.
b) Less effective than oil-based agents in improving pregnancy outcomes post-HSG [16–18].
c) Small risk of allergic reactions to iodine, particularly in hypersensitive individuals.

Medical Physics Considerations in Contrasodium Use

X-ray exposure in HSG is a particular concern due to the sensitivity of female reproductive organs to ionizing radiation. Therefore, the ALARA (As Low As Reasonably Achievable) principle must be applied. Technical parameters such as tube voltage (kV), tube current (mA), exposure time, source-to-image distance (SID), and fluoroscopy mode (continuous or pulsed) directly affect entrance surface dose (ESD) and effective dose [7].

Studies have shown that pulsed fluoroscopy and automated exposure control (AEC) can reduce radiation dose by 50% – 75% without compromising diagnostic quality [14]. Additional protection measures such as the use of lead aprons over the lower abdomen and ovarian shields are also recommended to minimize secondary exposure.

In clinical practice, the selection and use of contrasodium should consider:

a) Viscosity and osmolality appropriate for diagnostic needs and patient comfort.
b) Optimal X-ray energy (typically 70 – 90 kVp) to balance penetration and image contrast.
c) Dose monitoring to ensure safety, especially given the proximity to radiosensitive reproductive organs.

The role of the medical physicist is crucial in ensuring that HSG protocols meet established standards, both in terms of image quality and radiation protection for patients and healthcare personnel.

MEDICAL PHYSICS ASPECTS IN THE OPTIMIZATION OF HSG EXAMINATIONS

Optimization in hysterosalpingography (HSG) aims to achieve the highest possible diagnostic image quality while minimizing radiation exposure to the patient. Medical physics plays a central role in achieving this balance through the application of radiation physics principles, selection of optimal imaging parameters, and implementation of radiation protection protocols aligned with the ALARA (As Low As Reasonably Achievable) principle.

Selection of Imaging Parameters

Technical parameters significantly affect both image quality and patient dose. Medical physicists assist in determining the optimal combination of the following:

a) Tube voltage (kVp): Typically ranges between 70 – 90 kVp. Higher kVp enhances tissue penetration but may reduce image contrast. The choice should be tailored to the patient's body habitus and the contrast agent characteristics [3].
b) Tube current and exposure time (mAs): Should be adequate to ensure a sufficient signal-to-noise ratio (SNR) without unnecessarily increasing dose.
c) Beam collimation: Limiting the radiation field to the uterus and pelvic area reduces off-target exposure and improves local contrast [12].
d) Use of anti-scatter grids: These reduce scattered radiation but require adjustments in mAs due to partial absorption of primary photons.

Radiation Dose Measurement and Monitoring

An essential function of medical physics in HSG is quantifying patient dose, particularly given the sensitivity of the uterus and ovaries to ionizing radiation. Common parameters include:

a) Dose-Area Product (DAP): Expressed in $mGy \cdot cm^2$, representing total radiation dose multiplied by the irradiated area.
b) Entrance Surface Dose (ESD): The estimated dose to the skin surface at the X-ray entry point.
c) Ovarian Effective Dose (OED): Used to estimate risk to reproductive tissues and the probability of deterministic or stochastic effects.

Phantoms and dosimeters are utilized by medical physicists to verify actual dose levels and to develop protocols that maintain diagnostic quality while minimizing exposure.

Influence of Contrast Sodium's Physical Characteristics on Image Quality

Contrast agents enhance visualization of anatomical structures in X-ray-based procedures. The physical characteristics of contrast sodium (kontrasodium) directly influence image contrast, distribution, and patient comfort, and must be understood within the framework of medical physics.

a) **Iodine Content and High Atomic Number**

Contrast sodium contains iodine (Z = 53), a highly radiopaque element that enhances X-ray absorption via the photoelectric effect. This interaction is dominant in the 30 – 80 keV energy range used in diagnostic imaging. Higher iodine concentration (300 – 370 mg I/mL) increases:

- Linear attenuation coefficient, producing sharper contrast between the uterine/tubal lumen and surrounding tissues.
- Visualization of fine structures such as the fallopian tubes and uterine lumen [9].

However, increased iodine concentration must be balanced with patient comfort and radiation control.

b) **Osmolality**

Contrast sodium is hyperosmolar, meaning it has a higher osmolality than plasma. This affects:

- Patient comfort, as high osmolality may cause uterine cramping or pain.
- Contrast distribution, as high osmolality draws fluid from surrounding tissues, potentially impacting visibility.

While hyperosmolar agents like diatrizoate provide high image contrast, they can induce tubal spasms that hinder interpretation [10].

c) **Viscosity**

Viscosity influences injection speed and distribution:

- Moderate viscosity is preferred for controlled flow into the fallopian tubes.
- Low viscosity may result in rapid flow that impairs observation, whereas high viscosity complicates injection and increases discomfort.

Contrast sodium typically offers ideal viscosity for HSG compared to more viscous, oil-based agents.

d) **Surface Tension and Dispersion**

Surface tension characteristics affect the agent's ability to:

- Spread evenly across the endometrial cavity.
- Enter narrow fallopian tubes.

Uniform distribution supports better visualization of anomalies like polyps, septa, or tubal obstructions.

e) **Effect on Contrast-to-Noise Ratio (CNR)**

Contrast sodium improves CNR by:

- Enhancing intensity differences between contrast-filled structures and background tissues.
- Enhancing intensity differences between contrast-filled structures and background tissues.

However, uneven or overly rapid distribution may cause image artifacts.

Radiation Dose Optimization

Medical physicists play a critical role in ensuring that radiation doses during HSG remain within safe, diagnostically effective limits. Commonly used safety indicators include Entrance Surface Dose (ESD) and Effective Dose. A study in Nigeria reported ESD values between 15 – 34 mGy and effective doses from 1.2 – 2.5 mSv [7].

Key optimization strategies include:

- Use of pulsed fluoroscopy instead of continuous mode to reduce cumulative exposure time.
- Pemilihan tegangan tabung (kV) dan arus tabung (mA) yang sesuai, biasanya 70 – 90 kV dan < 200 mA.
- Use of additional filters and automatic exposure control (AEC) systems.
- Adjustment of source-to-image distance (SID) to minimize magnification and skin dose.

Such strategies help limit radiation to reproductive organs without compromising diagnostic accuracy [14].

Image Quality Evaluation

Medical physicists are responsible for assessing and maintaining image quality in HSG procedures. Key parameters include:

- Image contrast: Determined by the absorption difference between contrast sodium and soft tissue.
- Spatial resolution: The ability to distinguish fine anatomical details such as narrow fallopian tubes.
- Image noise: Influenced by the number of X-ray photons reaching the detector. Lower noise enhances diagnostic accuracy.

Physicists use phantom tests and image analysis to evaluate system consistency and dose density (DAP) as a surrogate for total exposure quality.

Contrast Sodium vs. Other Contrast Media

Contrast medium selection greatly influences image quality and biological risk. From a physics standpoint, water-soluble, low-osmolar contrast sodium offers several advantages:

- Reduced scatter due to uniform distribution and lower viscosity.
- High photoelectric interaction due to iodine content, enhancing X-ray absorption and visualization.
- Rapid clearance, reducing overall exposure time.

In contrast, oil-based agents like Lipiodol provide prolonged visualization but have higher viscosity and risks such as lipid embolism [3]. While both are radiographically effective, sodium-based agents are more manageable in terms of dose and distribution.

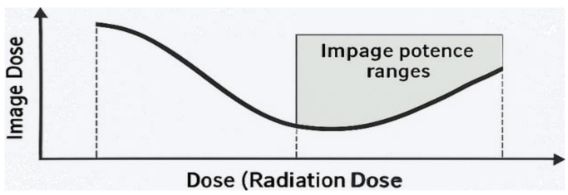

Figure 2. Dose vs image quality.

Table 3. Comparison of image quality between contrast sodium and oil-based media

Evaluation parameter	Contrast sodium (water-based)	Oil-based contrast
Radiographic Contrast	High	Very High
Image Sharpness (Resolution)	Good	Good
Visualization Duration	Short (~5 min)	Long (~30 min)
Distribution in Cavity	Even	Often localized
Image Artifacts	Minimal	Potential bubbles
Noise Risk	Low (fluoroscopy)	Low
Total Radiation Dose	Lower	Higher

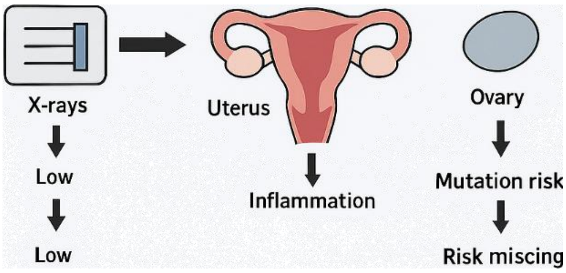

Figure 3. Radiation effects on female reproductive organs.

SAFETY AND SIDE EFFECTS OF CONTRASODIUM USAGE

Radiation protection for women of reproductive age is of critical importance. The principles of Justification and Optimization established by the International Commission on Radiological Protection (ICRP) are implemented in every imaging procedure.

Key measures include:

- Shielding, such as the use of lead aprons over the lower pelvis.
- Digital recording of exposure parameters for dose auditing purposes.
- Routine monitoring of the X-ray system by medical physicists, including detector calibration and QA/QC testing.

In cases where pregnancy is suspected, the medical physicist plays a vital role in estimating fetal dose and associated risks, and may recommend alternative protocols or delay the examination [15–17]. Potential risks and adverse effects include:

- Allergic reactions and hypersensitivity responses.
- Biological effects of radiation exposure on reproductive organs.
- Preventive actions and incident management.

LITERATURE REVIEW

Previous Studies on the Effectiveness of Contrasodium in HSG

Several studies support the effectiveness of water-based iodinated contrast media (contrasodium) in enhancing visualization of the female reproductive tract. Roest et al. (2020) reported that the use of contrasodium yielded adequate diagnostic outcomes in detecting fallopian tube occlusion, abnormal uterine structure, and intra-cavitary adhesions, with a sensitivity ranging from 81% – 90% [6]. Furthermore, contrasodium allows real-time morphological imaging of the uterus via fluoroscopy, enabling immediate interpretation by gynecologists.

Ahinko-Hakamaa et al. (2020) noted that water-based contrast is more easily absorbed by the body and rarely causes severe side effects such as embolism or intense pain [12]. Moreover, the duration of X-ray exposure tends to be shorter due to the rapid visualization of the contrast medium, making it suitable for low-radiation protocols.

Comparative Clinical Outcomes Using Different Contrast Media

Several studies have compared the clinical effectiveness of water-based (contrasodium) versus oil-based contrast agents. A meta-analysis by Tsui and Sofy (2023) revealed that oil-based contrast increased the likelihood of spontaneous pregnancy after HSG, with an odds ratio of 1.51 (95% CI: 1.23 – 1.86) [5]. However, this benefit was counterbalanced by a higher risk of intravasation and lipid embolism, particularly in patients with a history of pelvic surgery or endometriosis.

A randomized controlled trial by Dreyer et al. (2017) found that the pregnancy rate within six months post-HSG was higher in the oil-based group (39.7%) compared to the water-based group (29.1%), although the difference was not statistically significant after adjusting for age and BMI [18].

From a safety perspective, oil-based contrast agents have a higher intravasation rate (4.8% vs. 1.3%), as reported in a national survey in the Netherlands by Roest et al. (2020), although no fatal incidents were observed [6]. Therefore, the choice of contrast medium should consider the patient's risk factors, clinical indications, and institutional capabilities.

Table 4. Variation in radiation dose during HSG examinations.

Study	Country	Effective Dose (mSv)	Notes
[7]	Nigeria	1.2 – 2.5	High dose variation among hospitals
[8]	Sudan	1.6 – 4.3	ESD up to 35.7 mGy
[19]	Global	< 2 (recommended)	Emphasis on protecting women of reproductive age
[6]	Netherlands	1.9 (average)	National survey of 5,165 patients

Studies on Radiation Dose and Risk Management in Women of Reproductive Age

Several studies have evaluated the radiation dose received by patients during HSG procedures and how technical settings influence biological risk. Achuka et al. (2020) studied patients in Nigeria and found effective doses ranging from 1.2 to 2.5 mSv, whereas in Sudan, doses reached up to 4.3 mSv [7], indicating substantial inter-facility variability.

Kamburoğlu et al. (2019) concluded that pulsed fluoroscopy, optimization of kV/mAs, and the use of automatic exposure control (AEC) can reduce the dose by 40% – 70% without compromising image quality [14]. Medical physicists play a vital role in developing low-exposure protocols, implementing dose auditing systems, and ensuring the use of organ shielding for the uterus and ovaries.

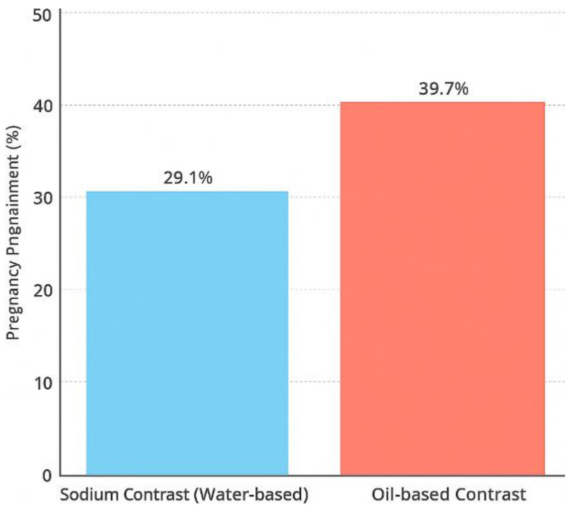

Figure 4. Pregnancy rate within six months following HSG [18].

The WHO (2016) also emphasized that X-ray exposure in women of reproductive age should be synchronized with the menstrual cycle and ideally avoided during the ovulatory and early luteal phases to minimize potential risks to the embryo in case of early conception [19].

DISCUSSION

Analysis of the Role of Medical Physics in the Diagnostic Effectiveness of HSG

The role of medical physics in Hysterosalpingography (HSG) examinations extends beyond merely setting technical parameters. It also encompasses aspects of safety, diagnostic effectiveness, and clinical efficiency. Previous studies [7] and [14] emphasized that interventions by medical physicists—such as adjusting tube voltage, exposure time, and selecting appropriate fluoroscopy modes—significantly contribute to reducing radiation exposure without compromising image quality.

This is particularly important since HSG is performed on women of reproductive age, who are especially sensitive to radiation, particularly in the ovaries and uterus. The optimization approach based on the ALARA (As Low As Reasonably Achievable) principle positions medical physics as a key discipline that bridges clinical needs with long-term patient safety.

Effectiveness of Sodium Contrast from Clinical and Medical Physics Perspectives

From a clinical perspective, sodium contrast offers excellent performance in visualizing the fallopian tubes and uterine cavity, with shorter imaging times and a better safety profile compared to oil-based contrast agents [4, 12]. For patients at risk of lipid embolism, sodium contrast is a rational choice due to its minimal intravasation and rapid elimination from the body. From the viewpoint of medical physics, sodium contrast offers several advantages:

- Uniform distribution within the cavity → avoids image artifacts or noise.
- Sufficient X-ray absorption → generates high-contrast images.
- Shorter exposure duration → reduces total patient dose.

However, its limitation lies in its shorter retention time, requiring faster and more precise fluoroscopic techniques. This demands high technical skills from the operator and exposure optimization from the medical physicist's side.

Clinical Outcome Comparison Between Contrast Agents

Although oil-based contrast has been associated with higher post-HSG pregnancy rates [18–20], this benefit is accompanied by a higher risk of side effects such as intravasation and lipid embolism [6]. Therefore, careful patient selection is crucial. In settings with limited resources and vulnerable populations, such as in developing countries, sodium contrast becomes a safer and more technically manageable option.

Medical physicists can assist clinicians in selecting risk-based protocols, for example by using dose modeling software (such as DoseWatch or PCXMC) to estimate radiation exposure effects on patients' reproductive organs.

Challenges and Recommendations

Identified challenges in the implementation of medical physics in HSG include:

- Lack of training for radiologic technologists on low-dose protocols.
- Variations in equipment quality and calibration across facilities.
- Not all hospitals have actively involved medical physicists.

Recommendations include:

- Implementation of standard operating procedures (SOPs) based on medical physics in all HSG procedures.
- Routine dose audits with transparent reporting.
- Training fluoroscopy operators on exposure control and image interpretation

CONCLUSION

Based on the literature review and analysis of the role of medical physics in Hysterosalpingography (HSG), several conclusions can be drawn. First, sodium contrast (a water-based contrast medium) is considered a safe, effective, and efficient option for HSG procedures. As a non-ionic iodinated compound, it possesses favorable physical properties that enable optimal X-ray absorption without significantly increasing biological risks. Second, the role of medical physicists is crucial in optimizing HSG procedures. Their involvement spans from setting technical parameters and managing radiation dose to evaluating diagnostic image quality. The application of the ALARA (As Low As Reasonably Achievable) principle serves as a fundamental guideline in performing HSG, particularly for women of reproductive age. Third, while oil-based contrast agents have been associated with higher pregnancy rates following HSG, they also carry greater risks of adverse effects such as intravasation and lipid embolism. In contrast, sodium contrast offers a better balance between image quality and biological safety. Fourth, radiation doses in HSG procedures vary globally and are heavily influenced by equipment quality, operator competence, and the active presence of medical physicists at healthcare facilities. According to WHO recommendations, the effective dose should not exceed 2 mSv per procedure.

To improve the overall quality and safety of HSG examinations, several recommendations are proposed. First, all reproductive radiology centers should involve medical physicists actively in the planning, execution, and evaluation of HSG, particularly regarding low-dose protocols and image quality assessment. Second, ongoing training for radiographers and gynecologists is essential, especially in the application of pulsed fluoroscopy, Automatic Exposure Control (AEC), and protective shielding for reproductive organs. Third, the selection of contrast media should be tailored to the patient’s risk profile and specific clinical objectives (e.g., pure diagnostic versus fertility-enhancing procedures). Patients at risk of lipid embolism should avoid oil-based contrast agents. Finally, further local and national research is urgently needed to collect comprehensive HSG dose data in Indonesia. This is critical given the current lack of population-based data, which hinders the development of effective regulations and the establishment of national protocols.

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