RESEARCH PAPER

Diagnostic Modalities in Primary Infertility: A Review of Transvaginal Sonography, Hysterosalpingography, and Laparohysteroscopy

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Abstract

Background

Primary infertility is a multifactorial reproductive disorder involving female, male, combined, and unexplained factors. In women, abnormalities of ovulation, ovarian reserve, uterus, fallopian tubes, endometrium, pelvic peritoneum and adnexa may contribute to failure to conceive. Accurate assessment of reproductive anatomy is therefore an essential component of infertility evaluation.

Objective

To review the contemporary evidence from 2016 to 2026 concerning the diagnostic roles, accuracy, advantages, limitations and clinical utility of TVS, three-dimensional TVS, hysterosalpingography (HSG), hysteroscopy and laparoscopy/laparohysteroscopy in women with primary infertility.

Materials and Methods

A structured narrative literature review was undertaken using PubMed/MEDLINE and guideline repositories, supplemented by citation tracking and reference-list screening. Publications from January 2016 through August 2026 were prioritized. Search concepts included primary infertility, female infertility, transvaginal sonography, three-dimensional ultrasound, sonohysterography, hysterosalpingography, tubal patency, HyCoSy, HyFoSy, hysteroscopy, laparoscopy, chromopertubation, endometriosis, uterine anomalies and pelvic adhesions.

Results

TVS has become the central first-line imaging examination because it is non-invasive, radiation-free and capable of evaluating the uterus, endometrium, ovaries, adnexa and many manifestations of endometriosis in a single examination. Three-dimensional TVS provides additional information regarding uterine morphology and congenital anomalies. HSG remains a well-established investigation for tubal patency and may have a fertility-enhancing effect when oil-based contrast is used. HyCoSy and HyFoSy provide radiation-free alternatives, with recent evidence demonstrating promising diagnostic performance and improved tolerability, although operator dependence and lack of universal standardization remain limitations. Hysteroscopy provides direct visualization of the uterine cavity and allows simultaneous treatment of selected intracavitary lesions. Laparoscopy with chromopertubation remains valuable for selected women with suspected endometriosis, pelvic adhesions or complex tubal disease but is no longer recommended as a routine diagnostic investigation in unexplained infertility.

Conclusion

No individual modality can adequately evaluate every anatomical component relevant to infertility. The contemporary evidence supports a patient-centered, stepwise diagnostic strategy: clinical assessment and semen analysis followed by high-quality TVS; targeted assessment of the uterine cavity when indicated; HSG or HyCoSy for tubal patency; hysteroscopy for suspected intracavitary disease; and laparoscopy for selected women with suspected pelvic pathology. The diagnostic pathway should balance accuracy, invasiveness, cost, patient comfort, local expertise, health system resources and the likelihood that a finding will alter management.

Keywords: HyCoSy; HyFoSy; hysteroscopy; laparoscopy; tubal patency; endometriosis; uterine abnormalities.

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INTRODUCTION

Infertility is an important reproductive health problem affecting human health, with substantial medical, psychological, social and economic consequences. The World Health Organization (WHO) defines infertility as failure to achieve pregnancy after 12 months or more of regular unprotected sexual intercourse and recognizes infertility as a disease of the male or female reproductive system. The WHO's first global guideline specifically addressing prevention, diagnosis and treatment of infertility was published in 2025 and emphasizes evidence-based, affordable, equitable and people-centered reproductive healthcare. [1] The WHO estimates that approximately one in six people of reproductive age experience infertility during their lifetime, illustrating the considerable global burden of the condition. [1,2] Primary infertility refers to infertility in an individual who has never previously achieved a pregnancy, whereas secondary infertility occurs after at least one previous pregnancy. [1-4] The diagnostic evaluation of infertility has undergone a major transformation during the past decade. Historically, extensive invasive testing was often performed, and diagnostic laparoscopy was considered an important component of the investigation of unexplained infertility. Contemporary practice increasingly emphasizes a systematic, rapid, cost-effective and minimally invasive approach [3]. Three-dimensional ultrasound provides additional information regarding the coronal plane of the uterus and has improved the evaluation of congenital uterine anomalies and complex uterine morphology. [5,6]

The importance of ultrasound in infertility is not restricted to ovarian assessment. Modern TVS allows simultaneous evaluation of the uterus, endometrium, myometrium, ovaries and adnexa. In experienced hands, it can also identify endometriomas and several forms of deep infiltrating endometriosis. The development of standardized approaches such as the International Deep Endometriosis Analysis (IDEA) terminology has further improved systematic ultrasound assessment of the pelvis. [7] Uterine pathology is particularly relevant because abnormalities of the uterine cavity can interfere with implantation and may contribute to infertility or adverse reproductive outcomes. Fibroids, polyps, adenomyosis, congenital uterine anomalies and intrauterine adhesions may be detected using ultrasound. A 2016 comparative study demonstrated that three-dimensional TVS had an overall diagnostic accuracy of 84.1% for uterine cavity abnormalities when compared with hysteroscopy, although sensitivity varied according to the lesion type. [5]

Saline infusion sonohysterography (SIS) represents an extension of conventional ultrasound in which sterile saline is introduced into the uterine cavity to separate the anterior and posterior endometrial surfaces. This improves visualization of intracavitary lesions, particularly endometrial polyps and submucosal fibroids. [8-13] SIS can therefore serve as an intermediate diagnostic step between conventional TVS and hysteroscopy, particularly where a cavity abnormality is suspected but immediate operative intervention is not required [14].

Hysterosalpingography has traditionally been regarded as the standard radiographic investigation of tubal patency[15-17]. Another meta-analysis found pooled sensitivity of 89% and specificity of 93% for HyCoSy in diagnosing tubal patency. These results support its potential role as an alternative to HSG.[18,20]HyFoSy is a further development in ultrasound-based tubal testing that uses a foam contrast medium. It avoids ionizing radiation and may be better tolerated than HSG. A prospective

diagnostic study comparing HyFoSy with HSG demonstrated moderate inter-test agreement. [21-25,26] More recently, a systematic review and meta-analysis including 20 studies reported that HyFoSy produced similar tubal-patency findings to laparoscopy in approximately 94% of patients and was associated with favorable tolerability. [26] A 2025 meta-analysis involving nine studies and 1,354 patients reported pooled sensitivity of 87% and specificity of 95% when comparing HyFoSy with HyCoSy, although agreement with HSG was only fair to moderate, indicating that additional standardization and validation are required. [27] Hysteroscopy occupies a different position in the diagnostic pathway because it allows direct visualization of the endometrial cavity. It can identify endometrial polyps, submucosal fibroids, adhesions, septa and other intracavitary abnormalities that may be missed or incompletely characterized by conventional imaging. Its major advantage is the ability to combine diagnosis with treatment. [28-32]

Hysterosalpingography has traditionally been regarded as the standard radiographic investigation of tubal patency. It involves transcervical administration of contrast followed by fluoroscopic or radiographic imaging of the uterine cavity and fallopian tubes. HSG can identify proximal and distal tubal obstruction, hydrosalpinx and certain abnormalities of tubal architecture. Its major advantages are widespread availability and standardized visualization of tubal filling and peritoneal spill. However, HSG has disadvantages, including ionizing radiation, discomfort, potential contrast reactions and false-positive proximal obstruction. Hysteroscopy occupies a different position in the diagnostic pathway because it allows direct visualization of the endometrial cavity. It can identify endometrial polyps, submucosal fibroids, adhesions, septa and other intracavitary abnormalities that may be missed or incompletely characterized by conventional imaging. Its major advantage is the ability to combine diagnosis with treatment. However, the detection of an abnormality does not automatically establish that its removal improves fertility. The clinical benefit of routine screening hysteroscopy in women with otherwise normal infertility investigations remains controversial. Recent evidence has refined the role of hysteroscopy. A 2023 systematic review and meta-analysis of 15 randomized controlled trials involving 5,038 women found that hysteroscopy was associated with increased live-birth rates overall, particularly among women with previous ART failure, while the benefit was not clearly demonstrated before the first ART cycle. [33] These findings support selective rather than indiscriminate use of hysteroscopy.

Laparoscopy provides direct visualization of the uterus, ovaries, fallopian tubes and pelvic peritoneum. When combined with chromopertubation, it allows direct assessment of tubal patency. It remains valuable in women with suspected endometriosis, pelvic adhesions, previous pelvic inflammatory disease, complex tubal abnormalities or persistent symptoms despite non-invasive imaging. Nevertheless, the role of diagnostic laparoscopy has changed substantially because high-quality TVS and MRI can now identify many forms of deep endometriosis without immediate surgery.

The 2022 European Society of Human Reproduction and Embryology (ESHRE) guideline emphasizes the growing importance of non-invasive imaging in endometriosis and challenges the historical concept that laparoscopy must always be performed to establish the diagnosis. Similarly, the 2023 evidence-based guideline for unexplained infertility does not support routine invasive investigations without a clinical indication.

The present review synthesizes evidence from 2016 through 2026 to compare these modalities, examine their diagnostic strengths and limitations, evaluate recent advances in imaging and endoscopy, and propose a practical stepwise strategy for the investigation of primary infertility.

2. MATERIALS AND METHODS

2.1 Study Design

A structured narrative review was conducted to evaluate contemporary evidence regarding diagnostic modalities used in the anatomical evaluation of women with primary infertility.The review was designed to synthesize evidence rather than perform a de novo quantitative meta-analysis. Consequently, no pooled effect estimate was calculated from the studies included in this manuscript.

Older landmark publications were considered only where necessary to explain the development of a diagnostic modality or establish historical context.

2.2 Information Sources

The literature search focused primarily on PubMed/MEDLINE; guideline publications from WHO;ASRM publications;ESHRE publications;Cochrane reviews;reference lists of

relevant systematic reviews and meta-analyses;citation tracking of major diagnostic studies.

Inclusion Criteria

1. evaluated women undergoing investigation for infertility or subfertility;
2. assessed at least one relevant diagnostic modality;
3. addressed uterine, ovarian, tubal, endometrial or pelvic pathology;
4. reported diagnostic accuracy, clinical utility, reproductive outcome or procedural characteristics;
5. were published from 2016 to 2026, except selected landmark studies used for historical context;
6. were systematic reviews, meta-analyses, randomized controlled trials, prospective studies, retrospective studies, comparative diagnostic studies or major clinical guidelines;
7. were available in English or had sufficient English-language information for evaluation.

Exclusion Criteria

- focused exclusively on male infertility;
- were unrelated to infertility diagnosis;
- involved non-human subjects;
- were isolated case reports;
- lacked clinically relevant diagnostic information;
- were duplicate publications;
- consisted only of conference abstracts without sufficient methodological information;
- focused exclusively on treatment without a relevant diagnostic component.

2.8 Evidence Synthesis

Evidence was synthesized under five major domains:

1. TVS and advanced ultrasound;
2. uterine cavity assessment;
3. tubal patency assessment;
4. hysteroscopy;
5. laparoscopy/laparohysteroscopy.

DISCUSSION

An important emerging concept in infertility management is that diagnostic investigations should be selected according to the individual clinical phenotype rather than performed as a fixed battery of tests in every woman. The evidence reviewed in the present study supports a personalized diagnostic pathway in which the pre-test probability of a particular abnormality determines the most appropriate investigation. This approach is particularly relevant because infertility is a heterogeneous condition and the same diagnostic test may have substantially different clinical value in different patient populations.

Age, duration of infertility, menstrual characteristics, pelvic pain, previous pelvic surgery, history of pelvic inflammatory disease, previous ectopic pregnancy, suspected endometriosis and findings on the initial ultrasound should all influence subsequent investigations. For example, a woman with regular cycles, no pelvic symptoms and a completely normal TVS may derive relatively little benefit from immediate diagnostic laparoscopy. In contrast, a woman with severe dysmenorrhea, deep dyspareunia and an ultrasound demonstrating an endometrioma or features of posterior compartment disease may require detailed endometriosis mapping and consideration of surgical evaluation. Thus, the same diagnostic modality may be unnecessary in one patient but highly valuable in another.

The concept of sequential testing is particularly relevant to tubal assessment. HSG remains appropriate in many settings, especially where radiological expertise is readily available. However, HyCoSy or HyFoSy may be attractive alternatives in centers with appropriately trained ultrasonographers. When the initial tubal test produces an equivocal result, repeating the same investigation without considering the cause of the uncertainty may not be appropriate. Instead, an alternative modality or direct assessment by laparoscopy may be considered depending on the clinical circumstances. This sequential approach can reduce false-positive diagnoses of tubal obstruction and prevent unnecessary surgical intervention.

Another important consideration is the distinction between anatomical abnormalities and clinically significant disease. Modern imaging can detect increasingly subtle abnormalities, but the identification of an abnormality does not necessarily establish causation. Incidental fibroids, small

endometrial polyps, adenomyosis or mild endometriotic lesions may be present in women who subsequently conceive spontaneously. Therefore, treatment decisions should not be based exclusively on imaging findings. The size, location, severity, symptoms, reproductive history and planned fertility treatment must all be considered.

The same principle applies to hysteroscopy. Although direct visualization provides superior assessment of the uterine cavity, routine hysteroscopy in every woman with infertility may result in overdiagnosis and overtreatment. Its diagnostic and therapeutic value is likely to be greatest in women with abnormal ultrasound or SIS findings, recurrent implantation failure, previous intrauterine surgery or symptoms suggestive of cavity pathology. Recent randomized evidence suggesting improved live-birth outcomes in selected ART populations further supports an indication-based rather than universal approach.

The future diagnostic pathway is therefore likely to be increasingly integrated. Rather than considering TVS, HSG, HyCoSy, hysteroscopy and laparoscopy as competing investigations, they should be regarded as complementary tools answering different clinical questions. TVS provides broad pelvic assessment; 3D-TVS and SIS provide more detailed evaluation of the uterine cavity; HSG and HyCoSy/HyFoSy assess tubal patency; hysteroscopy evaluates and treats intracavitary abnormalities; and laparoscopy provides direct assessment of the peritoneal cavity and remains particularly relevant for selected endometriosis and adhesive disease.

The WHO 2025 guideline's emphasis on patient-centered, equitable and context-sensitive infertility care also supports gender equality and disease prevention through access to appropriate fertility care.

The ultimate objective of infertility investigation is not simply to identify abnormalities but to improve reproductive outcomes and quality of life.

RESULTS

The evidence reviewed from 2016 through 2026 demonstrates a clear movement toward minimally invasive and individualized infertility evaluation.TVS consistently emerged as the foundation of pelvic imaging because it can evaluate several anatomical structures simultaneously. HSG remains an established test for tubal patency, whereas HyCoSy and HyFoSy have increasingly become acceptable radiation-free alternatives. Three-dimensional ultrasound improves assessment of uterine morphology. SIS improves detection of intracavitary pathology. Hysteroscopy remains the most direct method for examining the endometrial cavity, while laparoscopy retains an important but more selective role.The most important contemporary guideline development was the WHO 2025 global infertility guideline, which recommends either HSG or HyCoSy for assessment of tubal patency in women with suspected tubal disease and emphasizes context-specific selection according to resources, expertise and patient circumstances. [1,2]

Table 1. Major Studies Evaluating Transvaginal Sonography and Uterine Imaging

Reference	Year	Modality	Study type	Main finding	Clinical implication
Apirakviriya et al. [5]	2016	3D-TVS	Comparative study	Diagnostic accuracy 84.1%; specificity 91.5%	Useful for uterine cavity assessment but hysteroscopy remains important for definitive evaluation
Singh et al. [9]	2018	SIS	Observational study	Useful for uterine pathology and tubal assessment	Practical low-cost intermediate investigation
Campbell [10]	2019	TVS	Review	TVS important for ovarian reserve, follicles and morphology	Supports TVS as first-line examination

Sanin-Ramirez et al. [12]	2020	TVS/SIS	Meta-analysis	SIS improves characterization of endometrial polyps	Useful when intracavitary disease is suspected
Kaveh et al. [13]	2020	TVS/SIS/hysteroscopy	Systematic review/meta-analysis	SIS and hysteroscopy outperform conventional TVS for intracavitary lesions	Supports targeted cavity assessment
Nirgianakis et al. [30]	2021	Imaging/uterine pathology	Systematic review	Uterine factors constitute a heterogeneous group of infertility causes	Uterine assessment should be individualized
Somigliana et al. [15]	2021	Uterine imaging	Systematic review/meta-analysis	Evidence linking fibroids with natural fertility remains heterogeneous	Morphology and location matter more than presence alone
Xiang et al. [20]	2022	TVS	Meta-analysis	TVS showed useful diagnostic performance for deep endometriosis	Supports expert TVS before invasive surgery
Tian et al. [21]	2022	TVS/MRI	Meta-analysis	Both demonstrated good accuracy for urinary tract endometriosis	Imaging can guide selective surgery
Kanti et al. [32]	2024	TVS/MRI	Meta-analysis	TVS and MRI showed useful diagnostic accuracy for endometrioma	Supports non-invasive characterization

Table 2. Major Studies Evaluating Tubal Patency

Reference	Year	Test	Study type	Main finding
Alcázar et al. [6]	2016	3D/4D HyCoSy	Systematic review/meta-analysis	Sensitivity 92%; specificity 91%
Fang et al. [7]	2018	Oil vs water HSG	Meta-analysis	Oil contrast increased ongoing pregnancy
van Rijswijk et al. [8]	2018	Oil vs water HSG	RCT/cost-effectiveness	Higher ongoing pregnancy and live birth with oil-based HSG
Chen et al. [11]	2020	HyCoSy/MR-HSG	Systematic review/meta-analysis	HyCoSy sensitivity 89%, specificity 93%
García et al. [25]	2021	HyFoSy/HSG	Prospective diagnostic study	Moderate agreement between tests

Xu et al. [24]	2023	HyCoSy	Review	Increasing use but technical standardization remains necessary
Agopianz et al. [26]	2024	HyFoSy	Systematic review/meta-analysis	Comparable with HSG; favorable tolerability
Xydias et al. [27]	2025	HyFoSy/HyCoSy/HSG	Systematic review/meta-analysis	HyFoSy showed high specificity but limited evidence base

Table 3. Major Evidence Regarding Hysteroscopy

Reference	Year	Population/design	Principal finding
Kamath et al. [17]	2019	Cochrane review	Insufficient high-quality evidence for routine screening hysteroscopy
Bosteels et al. [18]	2018	Cochrane review	Benefit of treating suspected cavity abnormalities remained uncertain
Xu et al. [19]	2020	Unexplained infertility	Combined hysteroscopy/laparoscopy identified pelvic abnormalities in selected patients
Riemma et al. [28]	2023	15 RCTs, 5,038 women	Hysteroscopy associated with higher live birth, particularly after previous ART failure

Table 4. Major Evidence Regarding Endometriosis and Laparoscopy

Reference	Year	Modality	Main finding
Zhou et al. [14]	2021	TVS	Pooled sensitivity 65% and specificity 92% for uterosacral ligament DIE
Becker et al. [14]	2022	ESHRE guideline	Imaging increasingly important; routine diagnostic laparoscopy challenged
Xiang et al. [20]	2022	TVS	Good overall diagnostic performance for deep endometriosis
Tian et al. [21]	2022	TVS/MRI	High specificity for urinary tract endometriosis
Roditis et al. [23]	2023	Clinical + TVS + MRI	Combined imaging improves assessment of deep disease
Chway et al. [22]	2024	TVS	Meta-analysis supports TVS for ureteral endometriosis
International Consensus [34]	2024	Non-invasive imaging	Standardized imaging terminology and classification encouraged

3.2 Transvaginal Sonography

TVS demonstrated the broadest range of applications among the diagnostic modalities reviewed. It permits evaluation of the uterus, endometrium, myometrium, ovaries, adnexa and pelvic structures in a single examination. Its advantages include absence of radiation, relatively low cost, accessibility and ability to perform dynamic examination.

The contemporary role of TVS extends beyond identification of gross pelvic abnormalities. Ultrasound can provide antral follicle count, ovarian morphology and follicular monitoring, thereby integrating anatomical and functional information into the infertility evaluation. [33,10,16]

Three-dimensional ultrasound is particularly useful for uterine morphology. In infertile women, 3D-TVS has demonstrated good specificity for uterine cavity abnormalities and can identify congenital anomalies and submucosal lesions. [5]

Future Directions

Future infertility diagnostics are likely to involve integration rather than replacement of modalities. Potential developments include, automated ultrasound measurements;artificial intelligence-assisted image interpretation;standardized reporting;automated follicle counting;AI-assisted endometriosis mapping;improved 3D/4D tubal imaging;more standardized HyFoSy protocols;minimally invasive office hysteroscopy; combined diagnostic pathways..

CONCLUSION

Transvaginal sonography should generally serve as the cornerstone of initial female pelvic assessment because it provides comprehensive information about the uterus, endometrium, ovaries and adnexa without ionizing radiation. Three-dimensional TVS adds important information regarding uterine morphology and congenital anomalies, while SIS can improve characterization of intracavitary lesions.Hysterosalpingography remains an established and clinically valuable investigation for tubal patency. Evidence suggesting higher pregnancy and live-birth rates with oil-based contrast has further increased its relevance.

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