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Review Article

UTERINE RECEPTIVITY AND APPLEBAUM UTERINE SCORING SYSTEM: A REVIEW WITH AN AYURVEDIC PERSPECTIVE

Anila M[1], Haripriya R.I[2]*

[1]Associate Professor, *[2]PG Scholar, Dept. of Prasutitantra and Striroga, Government Ayurveda College, Thiruvananthapuram, Kerala, India.

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ABSTRACT

Implantation requires a synchronized interaction between competent embryo and receptive endometrium. Uterine receptivity is a multidimensional phenomenon involving endometrial morphology, vascularity, myometrial activity, hormonal regulation and molecular signalling. Transvaginal ultrasonography provides a non-invasive approach to assess several of these characteristics. The uterine biophysical profile proposed by Applebaum integrates multiple sonographic and doppler parameters into a composite uterine scoring system. Objective is to review the contemporary understanding of uterine receptivity, describe the parameters of the Applebaum Uterine Scoring System for reproduction, and examine their possible interpretive relationship with Ayurvedic concepts relevant to female infertility, particularly *Garbha Sambhava Samagri, Vandhyatwa* and *Kshetra Dushti*. Modern evidence indicates that no single ultrasound variable completely characterizes uterine receptivity. Endometrial thickness, trilaminar morphology, endometrial vascularity, uterine artery doppler, myometrial echogenicity and uterine peristalsis provide complementary information, but their predictive value varies across populations and clinical settings. The Applebaum system is notable because it considers the uterus as an integrated functional unit. Ayurveda describes successful conception through the coordinated integrity of *Ritu, Kshetra, Ambu* and *Beeja,* with additional emphasis on *Dosha, Dhatu, Srotas* and *Apana Vata*. *Kshetra Dushti* can be discussed as an interpretive framework for impaired uterine readiness, but it should not be equated directly with any single modern ultrasound abnormality. Applebaum scoring offers a practical multidimensional ultrasound framework for describing uterine readiness, while Ayurveda provides a broader systems-oriented model of reproductive health. Prospective studies are required to determine whether Ayurvedic interventions can modify individual Applebaum parameters and clinically relevant fertility outcomes.

INTRODUCTION

Infertility is a major reproductive-health concern. The World Health Organization estimates that approximately one in six people of reproductive age experience infertility during their lifetime. Female infertility may arise from disorders involving the ovaries, uterus, fallopian tubes, endocrine system or multiple interacting factors, while a proportion remains unexplained. Within this multifactorial setting, implantation represents a critical transition between fertilization and clinically established pregnancy.[1]

Uterine receptivity refers to the transient state in which the endometrium is appropriately prepared to permit blastocyst apposition, adhesion and invasion. This state develops through coordinated hormonal, cellular, vascular and molecular changes during the mid-luteal phase. Although the concept is frequently discussed in relation to the 'window of implantation' (WOI), receptivity is not a single measurable variable. It is better regarded as a dynamic biological phenotype resulting from synchronization between embryo development and endometrial maturation.[2]

Clinical assessment has therefore evolved from isolated measurements of endometrial thickness to a broader evaluation involving endometrial morphology,

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vascularity, uterine artery flow, and uterine peristalsis. The Applebaum Uterine Scoring System for Reproduction, introduced in 1995, is important in this evolution because it combines several sonographic features into a composite score.[3]

From an Ayurvedic perspective, conception depends upon the appropriate functioning of *Ritu, Kshetra, Ambu* and *Beeja*, collectively described as *Garbha Sambhava Samagri*. *Kshetra* represents the reproductive field or uterine environment, while *Ambu* denotes the proper nourishment and impairment of these factors can be interpreted within the broader pathogenesis of *Vandhyatwa*. The present review explores how the modern concept of uterine receptivity and Applebaum parameters can be discussed alongside this Ayurvedic framework while maintaining appropriate scientific distinctions.[8]

MATERIALS AND METHODS

This review was prepared by reorganizing the contemporary peer-reviewed literature and authoritative sources. Modern literature was identified using PubMed-indexed publications and relevant evidence syntheses concerning endometrial receptivity, ultrasound markers, uterine vascularity, uterine peristalsis, the Applebaum scoring system and molecular receptivity testing. Classical Ayurvedic concepts were considered with reference to Charaka Samhita, Sushruta Samhita and Ashtanga Hridaya, together with published Ayurvedic reviews and clinical literature on thin endometrium and *Vandhyatwa*.[2,10]

OBSERVATION

Contemporary Concept of Uterine Receptivity

Endometrial receptivity is a hormonally regulated and time-limited state during which the endometrium becomes capable of supporting embryo implantation. Estrogen drives proliferative growth during the follicular phase, while progesterone after ovulation induces secretory transformation, stromal decidualization, altered epithelial function and immunological adaptation. The receptive phenotype involves interaction among steroid hormones, cytokines, growth factors, adhesion molecules, extracellular matrix components and vascular pathways.[2]

Implantation itself is conventionally described as a sequence of apposition, adhesion and invasion. The blastocyst first approaches and loosely contacts the endometrial epithelium, followed by more stable adhesion and trophoblastic invasion into the decidualized stroma. Leukemia inhibitory factor (LIF), integrins, selectins, vascular endothelial growth factor (VEGF) and other mediators contribute to this process. Thus, a morphologically adequate endometrium is necessary but not sufficient to establish implantation competence.[2]

The WOI is commonly described around cycle days 20–24 in an idealized 28-day cycle, although the timing is biologically variable and depends on ovulation and progesterone exposure rather than calendar day alone. Disturbances in hormonal signalling, decidualization, inflammation, immune regulation, vascularity or embryo–endometrial synchrony can alter implantation potential.[2]

Importantly, contemporary literature cautions against treating any single marker as a definitive diagnostic test of receptivity. Endometrial thickness, for example, has an association with IVF outcomes at the population level, but its discriminatory ability for an individual patient is limited. Similarly, molecular tests such as the Endometrial Receptivity Array have expanded the concept of personalized WOI assessment, but their clinical utility is context-dependent and remains an area of active investigation.[4,5,6]

Factors Affecting Low Uterine Receptivity

Low uterine receptivity is multifactorial. Structural factors include submucosal fibroids, endometrial polyps, congenital uterine anomalies and intrauterine adhesions. Functional factors include thin or poorly developed endometrium, altered decidualization, chronic endometrial inflammation, abnormal vascularity, endocrine disturbances and altered uterine contractility. Embryonic aneuploidy or developmental arrest may independently produce implantation failure; consequently, an abnormal implantation outcome should not automatically be attributed to the uterus.[2,4,5]

- Hormonal dysregulation and inadequate progesterone mediated endometrial maturation.
- Defective decidualization and altered epithelial–stromal signalling.
- Reduced or abnormal expression of adhesion molecules and cytokines.
- Altered angiogenesis and impaired endometrial or sub-endometrial perfusion.
- Abnormal uterine artery impedance and vascular resistance.
- Excessive or abnormal uterine peristalsis around embryo transfer.
- Chronic endometrial inflammation and altered immune tolerance.
- Structural distortion of the uterine cavity.
- Oxidative and metabolic disturbances that may affect endometrial cellular function.

These mechanisms explain why a multidimensional ultrasound approach may be more informative than thickness alone, while also explaining why even a favourable ultrasound profile cannot guarantee implantation.[4,5]

Ultrasound Assessment of Uterine Receptivity

Transvaginal ultrasonography is widely used because it is non-invasive, accessible and capable of assessing both morphology and haemodynamic features. Conventional assessment includes endometrial thickness and pattern, whereas Doppler techniques permit evaluation of uterine, endometrial and sub-endometrial vascularity. Three-dimensional ultrasound can additionally quantify endometrial volume and vascular indices.[5]

Endometrial thickness is commonly measured in the sagittal plane at the point of maximal thickness, excluding the hypoechoic myometrium. A thickness below approximately 7mm has frequently been associated with lower implantation or pregnancy rates in IVF populations; however, meta-analytic evidence indicates that thickness alone has limited ability to discriminate individual pregnancy outcomes. Therefore, a numerical threshold should not be interpreted as an absolute definition of receptivity.[4,5]

The trilaminar or triple-line pattern reflects characteristic echogenic changes during the late proliferative/periovulatory phase and has been associated with favourable reproductive outcomes in several studies. Nevertheless, the strength of association varies with population and timing of measurement.[5]

Endometrial and sub-endometrial vascularity can be assessed by colour or power doppler. Adequate perfusion is biologically relevant because implantation requires oxygen, nutrients, vascular remodelling and subsequent placentation. Studies using three-dimensional power doppler have reported associations between vascular indices and pregnancy outcomes, but standardization of equipment, timing and measurement remains necessary.[5]

Uterine artery Doppler, particularly the pulsatility index (PI), provides information about downstream uterine vascular impedance. Lower impedance may indicate improved uterine perfusion, although PI alone is not a definitive receptivity test. Myometrial echogenicity and uterine peristalsis provide additional information about the functional uterine environment.[5]

Applebaum Uterine Scoring System for Reproduction

Applebaum introduced the uterine biophysical profile in 1995 as a composite ultrasound-based assessment of uterine readiness. The Uterine Scoring System for Reproduction (USSR), also referred to as the uterine biophysical profile, integrates seven domains: endometrial thickness, endometrial layering, myometrial contractions, myometrial echogenicity, uterine artery Doppler flow, endometrial blood flow and myometrial blood flow. The composite score is intended to characterize the uterus as a functional unit rather than relying on a single sonographic marker.[3]

A commonly used 0–20 version of the system assigns weighted scores to the individual parameters. [3]

Table 1: Parameters of Applebaum Scoring System

Parameter	Typical Applebaum assessment	Maximum score	Physiological relevance
Endometrial thickness	<7 mm = 0; 7–9 mm = 2; 10–14 mm = 3; >14 mm = 1	3	Reflects endometrial development.
Endometrial layering	No layering = 0; hazy five-line appearance = 1; distinct five-line = 3	3	Reflects periovulatory endometrial architecture and tissue differentiation.
Myometrial contractions / endometrial motion	<3 contractions in 2 min = 0; ≥3 in 2 min = 3	3	Represents uterine contractile activity; excessive activity around embryo transfer may be unfavourable.
Myometrial echogenicity	Coarse/inhomogeneous = 1; relatively homogeneous = 2	2	Provides a grayscale description of the myometrium and may reflect structural/functional homogeneity.
Uterine artery Doppler flow (PI)	>3 =0; 2.5-2.99 = 0 2.2-2.49=1; < 2.19=2	2	Provides an indirect measure of uterine vascular impedance.
Endometrial blood flow	absent = 0; sparse = 2; multifocal = 5	5	Assesses vascular penetration into the endometrium; relevant to implantation and early placentation.
Myometrial blood flow	absent = 0; present = 2	2	Provides information on myometrial perfusion and the vascular environment surrounding the endometrium.

Clinical Interpretation of Individual Applebaum Parameters

Endometrial thickness

Thickness is a readily reproducible quantitative measure and remains one of the most commonly reported sonographic variables. In the Applebaum system, 10–14 mm receives the maximum score, whereas both a thin endometrium and marked thickening receive lower scores. Contemporary evidence supports an association between very thin endometrium and reduced pregnancy probability in IVF cohorts, but also demonstrates that thickness has limited discriminatory capacity when used alone. Thus, the Applebaum score can be understood as part of a composite profile rather than as a standalone clinical rule.[4,5]

Endometrial layering

The five-line or trilaminar appearance reflects the echogenic relationship between the endometrial cavity, functional layer and surrounding tissue during the periovulatory period. A distinct pattern is generally regarded as favourable. Loss or blurring of layering may indicate altered endometrial maturation, although interpretation is strongly dependent on the cycle phase and hormonal milieu.[5]

Endometrial blood flow

Applebaum places substantial weight on endometrial vascularity, particularly flow reaching the deeper endometrial zone. This is physiologically plausible because implantation requires a vascularized tissue capable of supporting decidualization and subsequent trophoblastic invasion. Three-dimensional Doppler studies have reported associations between endometrial/subendometrial vascular indices and pregnancy occurrence, but these measurements require standardized acquisition and remain probabilistic rather than diagnostic.

Myometrial blood flow

Myometrial perfusion is distinct from endometrial vascularity. The presence of intramyometrial flow indicates that the vascular environment of the uterine wall is demonstrable, but it should not be interpreted as proof of adequate endometrial perfusion. This distinction is particularly relevant when endometrial flow is present but myometrial flow is not clearly visualized or when vascularity differs across Doppler techniques.[5]

Uterine artery Doppler

Uterine artery PI provides an indirect assessment of vascular impedance. Higher resistance may indicate less favourable uterine haemodynamics, whereas lower resistance can be compatible with improved perfusion. However, uterine artery doppler is influenced by cycle phase, ovarian stimulation, technical factors and patient characteristics; therefore, its interpretation is best integrated with the other parameters.[5]

Myometrial echogenicity

Homogeneous myometrial echogenicity receives a higher score in the Applebaum system. The parameter is less frequently discussed than endometrial thickness or blood flow, but it contributes to the concept that the uterine wall itself forms part of the implantation environment. Heterogeneous echogenicity may prompt consideration of structural or myometrial pathology in the appropriate clinical context.

Myometrial contractions/endometrial motion

Uterine peristalsis changes across the menstrual cycle and may contribute to sperm transport, distribution of uterine fluid and embryo positioning. Excessive contractility around embryo transfer has been associated with lower clinical pregnancy rates in recent systematic reviews, although heterogeneity and uncertainty remain. The Applebaum system therefore captures a functional dimension that thickness and morphology cannot represent.[7]

Other Methods of Assessing Endometrial Receptivity

Histological dating, endometrial biopsy, immunohistochemical markers and transcriptomic assays have all been used to study receptivity. Molecular mediators include integrins, LIF, cytokines, growth factors and genes involved in decidualization and epithelial–stromal communication. The Endometrial Receptivity Array (ERA) is a transcriptomic approach intended to classify the endometrium as receptive, pre-receptive or post-receptive and to identify a personalized timing of embryo transfer in selected patients.[2,6]

However, the existence of a biological marker does not automatically establish clinical utility. Recent reviews emphasize that currently available tests do not consistently improve live-birth outcomes across all patient groups. Consequently, ultrasound-based scoring and molecular testing should be viewed as complementary research and clinical tools, with their indications determined by the specific reproductive context.[6]

Ayurvedic Perspective of Conception and Uterine Receptivity

Ayurveda approaches conception through a multidimensional model rather than through a single reproductive organ or parameter. *Garbha Sambhava Samagri* comprises *Ritu, Kshetra, Ambu* and *Beeja*. Sushruta describes these four as essential factors for formation of *Garbha*, while related Ayurvedic literature further emphasizes the role of *Dosha, Dhatu, Srotas*, mental state and functional integrity of *Apana Vata*.[8-10]

Ritu denotes appropriate reproductive timing and can be discussed in relation to ovulatory timing and the synchronization required between embryo development and endometrial maturation. *Kshetra* denotes the reproductive field, particularly the uterus and female reproductive tract, and has the closest conceptual relationship to the modern idea of a receptive uterine environment. *Ambu* represents nourishment and can be interpreted in relation to adequate nutritional and tissue support. *Beeja* refers to reproductive seeds or gametes and therefore relates broadly to gamete competence. [2,8–10]

Vandhyatwa and *Kshetra Dushti*

Vandhyatwa represents a broad Ayurvedic framework for infertility and may arise from disturbances in one or more components required for conception. *Kshetra Dushti* can be an important interpretive concept in cases where the uterine environment is inadequate for conception or implantation. Classical discussions also involve *Artava, Artavavaha Srotas, Dosha* imbalance, *Dhatu* nourishment and *Apana Vata*.[8–10]

From an integrative standpoint, *Kshetra Dushti* may be used as a clinical hypothesis for impaired uterine readiness when modern evaluation demonstrates thin endometrium, altered morphology, impaired vascularity, inflammatory uterine pathology or other abnormalities. This should be described as a conceptual correlation rather than a validated diagnostic equivalence. Modern conditions such as chronic endometritis, uterine anomalies and vascular impairment have specific pathological definitions that should be retained in contemporary reporting.[4,5,8–10]

Artava Kshaya, described in Ayurvedic literature by abnormalities such as reduced or delayed menstruation and painful menstruation, may coexist with disturbances of endometrial development. However, menstrual blood quantity or pain cannot independently establish endometrial receptivity. Rather, menstrual history can contribute to the broader assessment of reproductive physiology.[8–10]

Integrative Interpretation of Applebaum Parameters through an Ayurvedic Lens

The Applebaum system provides an opportunity to operationalize several aspects of uterine status that can be measured repeatedly by ultrasound. Ayurveda, in contrast, provides a broader explanatory model involving the condition of *Kshetra, Rasa–Rakta* nourishment, *Artava, Srotas* and functional *Dosha* balance. The most scientifically appropriate integration is therefore to use the modern parameter as the measurable endpoint and the Ayurvedic framework as a hypothesis-generating clinical context.[3,8–10]

Table 2: Possible Ayurvedic Interpretations

Applebaum domain	Possible Ayurvedic interpretive domain	Caution in interpretation
Endometrial thickness	*Kshetra* adequacy; *Rasa–Rakta/ Artava* nourishment	Not a direct measure of any single *Dhatu or Dosha*.
Endometrial layering	Qualitative integrity and maturation of *Kshetra*	Morphological imaging finding; cycle timing is essential.
Endometrial blood flow	*Kshetra* perfusion; nourishment of reproductive tissue	Doppler vascularity may not equivalent to *Ambu*.
Myometrial blood flow	Functional vascular support of *Garbhashaya*	May be complementary to, but is not interchangeable with, endometrial flow.
Uterine artery PI	Systemic and local circulatory support of *Kshetra*	PI is a haemodynamic measure influenced by multiple variables.
Myometrial echogenicity	Structural integrity of *Garbhashaya*	Non-specific; abnormal echogenicity needs modern clinical correlation.
Uterine contractions	*Apana Vata* and normal pelvic functional activity	Conceptual analogy only; *Apana Vata* has a wider classical meaning.

DISCUSSION

Modern evidence indicates that no single ultrasound variable completely characterizes uterine receptivity. Endometrial thickness, trilaminar morphology, endometrial/subendometrial vascularity, uterine artery Doppler, myometrial echogenicity and uterine peristalsis provide complementary information, but their predictive value varies across populations and clinical settings. The Applebaum system is notable because it considers the uterus as an integrated functional unit. Ayurveda describes successful conception through the coordinated integrity of *Ritu, Kshetra, Ambu* and *Beeja*, with additional emphasis on *Dosha, Dhatu, Srotas* and *Apana Vata*. *Kshetra Dushti* can be discussed as an

interpretive framework for impaired uterine readiness, but it should not be equated directly with any single modern ultrasound abnormality. [2–5,7–10]

Implications for Ayurvedic Research

Applebaum scoring may provide a useful objective outcome framework for Ayurveda-based clinical research on low uterine receptivity. Instead of relying only on subjective symptoms or menstrual characteristics, investigators can prospectively record endometrial thickness, layering, Doppler vascularity, uterine artery PI, myometrial echogenicity and uterine motion using a standardized protocol. This may allow reproducible evaluation of whether an intervention changes the sonographic uterine phenotype.[3,5,8–10]

Applebaum score should preferably be reported both as a continuous/ordinal outcome and by individual parameter because a total score can conceal which component has changed.[3]

CONCLUSION

Uterine receptivity is a dynamic, multidimensional process that depends on synchronized hormonal, morphological, vascular, mechanical, immune and molecular events. Transvaginal ultrasound provides a practical window into several of these features, while the Applebaum Uterine Scoring System is distinctive in combining endometrial and myometrial characteristics into a composite assessment of uterine readiness.

The major Applebaum scoring system domains- endometrial thickness, layering, uterine contractions, myometrial echogenicity, uterine artery Doppler, endometrial blood flow and myometrial blood flow- should be interpreted as complementary indicators rather than independent determinants of implantation. Contemporary evidence supports their potential clinical value but also highlights limitations in predictive accuracy and standardization.

Ayurveda offers a broader framework through *Garbha Sambhava Samagri* and the concepts of *Kshetra, Artava, Rasa–Rakta* nourishment, *Srotas* and *Apana Vata*. *Kshetra Dushti* provides a useful conceptual language for discussing impaired uterine readiness, but it should not be equated with any single ultrasound finding. A scientifically robust integrative approach therefore uses Applebaum parameters as objective measurable outcomes while using Ayurvedic principles to generate clinically testable hypotheses. This framework may support future research into personalized, multidimensional approaches to low uterine receptivity and infertility.

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***Address for correspondence**
Dr. Haripriya R.I
PG Scholar,
Dept. of Prasutitantra and Striroga,
Government Ayurveda College,
Thiruvananthapuram, Kerala.
Email: priyarenjith9495@gmail.com

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