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VARICOCELE IN ADOLESCENTS AND MEN OF REPRODUCTIVE AGE: CHALLENGES OF EARLY DETECTION AND PREVENTION

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Abstract: Varicocele represents one of the most prevalent correctable causes of male infertility and is particularly significant in adolescents and men of reproductive age. Characterized by abnormal dilation and tortuosity of the pampiniform venous plexus, varicocele is detected in approximately 15% of the general male population and in up to 35–40% of men presenting with primary infertility. In adolescents, its prevalence ranges from 10% to 20%, increasing with pubertal progression. Despite its high frequency, early detection remains suboptimal due to asymptomatic presentation, social stigma, limited awareness, and variability in screening practices. Pathophysiologically, varicocele contributes to impaired spermatogenesis through scrotal hyperthermia, hypoxia, oxidative stress, hormonal imbalance, and venous reflux. These mechanisms may result in testicular hypotrophy, reduced semen quality, and long-term reproductive dysfunction. Early diagnosis during adolescence is controversial, as not all cases progress to infertility; however, delayed intervention may lead to irreversible testicular damage. Preventive strategies include structured screening programs, standardized ultrasonographic criteria, public health education, and individualized risk stratification. This review synthesizes current scientific evidence regarding epidemiology, pathophysiology, diagnostic modalities, and preventive approaches. Emphasis is placed on balancing overtreatment and undertreatment while promoting evidence-based clinical decision-making. Early identification combined with appropriate monitoring and timely intervention may reduce future infertility burden and improve reproductive health outcomes in affected populations.

Keywords: Varicocele, Male infertility, Early detection, Reproductive health, Testicular hypotrophy, Doppler ultrasonography.

Аннотация: Варикоцеле является одной из наиболее распространённых корректируемых причин мужского бесплодия и имеет особое значение у подростков и мужчин репродуктивного возраста. Заболевание характеризуется патологическим расширением и извитостью вен лозовидного (пампиниформного) сплетения. Варикоцеле выявляется примерно у 15% общей мужской популяции и у 35–40% мужчин с первичным бесплодием. Среди подростков распространённость составляет 10–20% и увеличивается по мере полового созревания. Несмотря на высокую частоту, ранняя диагностика остаётся недостаточной вследствие бессимптомного течения, социальной стигматизации, недостаточной информированности и различий в скрининговых подходах. С патофизиологической точки зрения варикоцеле нарушает сперматогенез посредством

AMERICAN ACADEMIC PUBLISHER

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повышения температуры мошонки, гипоксии, оксидативного стресса, гормонального дисбаланса и венозного рефлюкса. Эти механизмы могут приводить к гипотрофии яичек, снижению качества спермы и долговременным репродуктивным нарушениям. Ранняя диагностика в подростковом возрасте остаётся дискуссионной, поскольку не все случаи прогрессируют до бесплодия; однако запоздалое вмешательство может вызвать необратимые повреждения ткани яичка. Профилактические стратегии включают организацию скрининговых программ, стандартизацию ультразвуковых критериев, повышение уровня общественного здравоохранения и индивидуализированную стратификацию риска. В данном обзоре обобщены современные научные данные по эпидемиологии, патофизиологии, методам диагностики и профилактике варикоцеле. Особое внимание уделено необходимости баланса между гипердиагностикой и недостаточным лечением, а также продвижению доказательной клинической практики. Ранняя идентификация, динамическое наблюдение и своевременное вмешательство могут снизить бремя мужского бесплодия и улучшить показатели репродуктивного здоровья.

Ключевые слова: варикоцеле, мужское бесплодие, ранняя диагностика, репродуктивное здоровье. гипотрофия яичек, допплерография,

Annotatsiya: Varikotsele erkaklar bepushtligining eng keng tarqalgan tuzatilishi mumkin bo‘lgan sabablaridan biri bo‘lib, ayniqsa o‘smirlar va reproduktiv yoshdagi erkaklar orasida katta ahamiyatga ega. Kasallik urug‘don atrofidagi pampiniform venoz chigalning patologik kengayishi va egri-bugri holatga kelishi bilan tavsiflanadi. Varikotsele umumiy erkaklar populyatsiyasining taxminan 15% ida, birlamchi bepushtlik bilan murojaat qilgan erkaklarning esa 35–40% ida aniqlanadi. O‘smirlar orasida uchrash darajasi 10–20% ni tashkil etib, balog‘at jarayoni davomida ortib boradi. Yuqori tarqalganligiga qaramay, kasallik ko‘pincha simptomsiz kechishi, ijtimoiy stigma, xabardorlikning yetarli emasligi va skrining amaliyotidagi farqlar sababli erta aniqlanish darajasi pastligicha qolmoqda. Patofiziologik jihatdan varikotsele skrotal gipertemiya, gipoksiya, oksidativ stress, gormonal nomutanosiblik va venoz reflyuks orqali spermatogenezning buzilishiga olib keladi. Natijada urug‘don gipotorfiyasi, sperma sifatining pasayishi va uzoq muddatli reproduktiv disfunksiya rivojlanishi mumkin. O‘smirlik davrida erta tashxis qo‘yish masalasi bahsli hisoblanadi, chunki barcha holatlar bepushtlikka olib kelmaydi; biroq kechiktirilgan davolash urug‘don to‘qimalarida qaytmas o‘zgarishlarga sabab bo‘lishi mumkin. Profilaktik chora-tadbirlar qatoriga tizimli skrining dasturlarini joriy etish, ultratovush mezonlarini standartlashtirish, aholining tibbiy savodxonligini oshirish va individual xavf stratifikatsiyasini qo‘llash kiradi. Mazkur sharh maqolada epidemiologiya, patofiziologiya, diagnostika usullari va profilaktika strategiyalari bo‘yicha zamonaviy ilmiy dalillar umumlashtirilgan. Davolashda ortiqcha aralashuv va yetarli bo‘lmagan muolaja o‘rtasida muvozanatni saqlagan holda, dalillarga asoslangan klinik qaror qabul qilish muhimligi ta’kidlanadi. Erta aniqlash, muntazam monitoring va o‘z vaqtida aralashuv kelajakdagi bepushtlik yukini kamaytirishi hamda reproduktiv salomatlik ko‘rsatkichlarini yaxshilashi mumkin.

Kalit so‘zlar: varikotsele, erkaklar bepushtligi, erta tashxis, reproduktiv salomatlik, urug‘don gipotorfiyasi, Doppler ultratovush.

Introduction: Varicocele is defined as abnormal dilatation and tortuosity of the pampiniform plexus veins within the spermatic cord, predominantly affecting the left side due to anatomical and hemodynamic factors. The condition has long been recognized as a significant contributor to

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male reproductive dysfunction. Epidemiological studies estimate its prevalence at approximately 15% in the general male population, rising to 20% among adolescents during late puberty. Among men evaluated for infertility, varicocele is identified in nearly one-third of cases with primary infertility and up to 70–80% in those with secondary infertility. These figures underscore its clinical importance, particularly in populations at the threshold of reproductive maturity.

The pathogenesis of varicocele is multifactorial. Anatomically, the left testicular vein drains into the left renal vein at a perpendicular angle, increasing hydrostatic pressure. Incompetent or absent venous valves further exacerbate venous reflux. Elevated venous pressure leads to pooling of blood in the pampiniform plexus, impairing the countercurrent heat exchange mechanism that normally maintains optimal scrotal temperature. Even a modest increase of 1–2°C above physiological levels can negatively affect spermatogenesis, as germinal epithelium is highly temperature-sensitive.

Beyond thermal dysregulation, oxidative stress plays a central role in varicocele-associated testicular damage. Increased reactive oxygen species (ROS) production within the testes can disrupt sperm DNA integrity, lipid membranes, and mitochondrial function. Clinical investigations have demonstrated higher levels of oxidative biomarkers and reduced antioxidant capacity in semen samples from men with clinically significant varicocele. Additionally, venous stasis may cause hypoxia and accumulation of toxic metabolites, further impairing Leydig and Sertoli cell function.

Hormonal disturbances, particularly reduced intratesticular testosterone levels, may also contribute to compromised spermatogenesis.

In adolescents, varicocele frequently emerges during rapid pubertal growth, coinciding with increased testicular blood flow and hormonal changes. Although many adolescents remain asymptomatic, some develop testicular asymmetry or hypotrophy, which may predict future impairment of fertility. The challenge lies in determining which patients will experience progressive deterioration and which will remain stable without intervention. Current clinical guidelines emphasize careful monitoring rather than routine surgical correction for all cases.

Diagnosis traditionally relies on physical examination, particularly palpation during the Valsalva maneuver. Varicoceles are graded clinically from I to III based on detectability and visibility. However, subclinical forms detectable only via Doppler ultrasonography complicate clinical decision-making. Doppler imaging allows objective measurement of venous diameter and reflux duration, improving diagnostic accuracy and enabling standardized follow-up.

Early detection strategies remain debated. Routine school-based screening programs are implemented in some countries, identifying adolescents with asymptomatic varicocele. However, the cost-effectiveness and long-term benefit of universal screening remain controversial. Concerns include overdiagnosis, unnecessary anxiety, and potential overtreatment. Conversely, delayed recognition may permit irreversible testicular damage before reproductive intentions arise.

Preventive considerations extend beyond early diagnosis to include patient education, lifestyle counseling, and risk assessment. Although primary prevention of anatomical venous

AMERICAN ACADEMIC PUBLISHER
INTERNATIONAL JOURNAL OF MEDICAL SCIENCES
ISSN NUMBER: 2692 - 5206 Volume 6. No 02. February ,2026

insufficiency is not feasible, secondary prevention—aimed at limiting progression and preserving testicular function—is attainable through timely surveillance and intervention.

This article examines the epidemiological trends, diagnostic complexities, and preventive challenges associated with varicocele in adolescents and men of reproductive age. By synthesizing contemporary scientific data, it aims to clarify current controversies and propose evidence-based strategies for optimizing reproductive outcomes while minimizing unnecessary interventions.

Materials and Methods: This scientific review was conducted through systematic analysis of peer-reviewed literature retrieved from major international medical databases. The research strategy was designed to ensure comprehensive coverage of epidemiological, clinical, and preventive aspects of varicocele in adolescents and men of reproductive age.

Electronic searches were performed in PubMed, Scopus, Web of Science, Embase, and the Cochrane Library. Additional sources were identified through Google Scholar and reference list screening of relevant review articles and clinical guidelines. Search terms included combinations of the following keywords: “varicocele,” “adolescent varicocele,” “male infertility,” “testicular hypotrophy,” “Doppler ultrasonography,” “oxidative stress,” “early detection,” “screening,” and “prevention.” Boolean operators were used to refine search results and increase specificity.

Inclusion criteria comprised peer-reviewed articles published in English between 2000 and 2024, including observational studies, randomized controlled trials, meta-analyses, systematic reviews, and doctoral dissertations addressing epidemiology, pathophysiology, diagnosis, treatment outcomes, or preventive strategies in adolescents or reproductive-aged males. Clinical guidelines from recognized urological associations were also included. Exclusion criteria encompassed case reports with fewer than ten participants, non-peer-reviewed publications, duplicate records, and studies lacking clear methodological transparency.

A total of 312 records were initially identified. After removal of duplicates and preliminary screening based on titles and abstracts, 148 articles underwent full-text evaluation. Ultimately, 86 high-quality sources met inclusion criteria and were incorporated into qualitative synthesis. Particular emphasis was placed on large-scale cohort studies, multicenter trials, and meta-analyses to ensure statistical reliability.

Data extraction focused on prevalence rates, age distribution, diagnostic criteria, semen parameter changes, hormonal profiles, ultrasonographic findings, oxidative stress markers, and outcomes following surgical or conservative management. Statistical data were analyzed descriptively, highlighting ranges and pooled estimates reported in the literature. When available, relative risk estimates and confidence intervals were considered to evaluate strength of association.

Quality assessment was performed using standardized appraisal tools appropriate to study design. Observational studies were evaluated for sample size adequacy, confounding control, and follow-up duration. Randomized trials were assessed for randomization methods, allocation concealment, and outcome reporting consistency. Meta-analyses were reviewed for heterogeneity and publication bias evaluation.

AMERICAN ACADEMIC PUBLISHER
INTERNATIONAL JOURNAL OF MEDICAL SCIENCES
ISSN NUMBER: 2692 - 5206 Volume 6. No 02. February ,2026

Given the ethical considerations inherent in adolescent populations, special attention was paid to studies addressing long-term reproductive outcomes and psychosocial implications of early diagnosis. The methodological approach prioritized balanced interpretation of findings to avoid overgeneralization.

This structured review methodology ensures that conclusions are grounded in robust scientific evidence and reflect contemporary understanding of varicocele-related reproductive health challenges.

Results; Analysis of the selected literature reveals consistent epidemiological and clinical patterns regarding varicocele in adolescents and reproductive-aged men. Prevalence studies confirm that varicocele is rare before puberty but increases significantly during adolescence. Population-based screenings report rates between 10% and 20% among boys aged 14–19 years, with higher incidence during Tanner stages IV and V. In adult males, overall prevalence stabilizes at approximately 15%, while infertility clinic cohorts demonstrate markedly higher rates, reaching 35–40% in primary infertility and exceeding 70% in secondary infertility cases.

Testicular volume asymmetry emerges as a key clinical marker in adolescents. Several longitudinal studies demonstrate that up to 20–30% of adolescents with grade II–III varicocele develop ipsilateral testicular hypotrophy exceeding 10–20% volume difference compared to the contralateral testis. Such asymmetry correlates with impaired semen parameters in early adulthood, suggesting progressive dysfunction in a subset of patients.

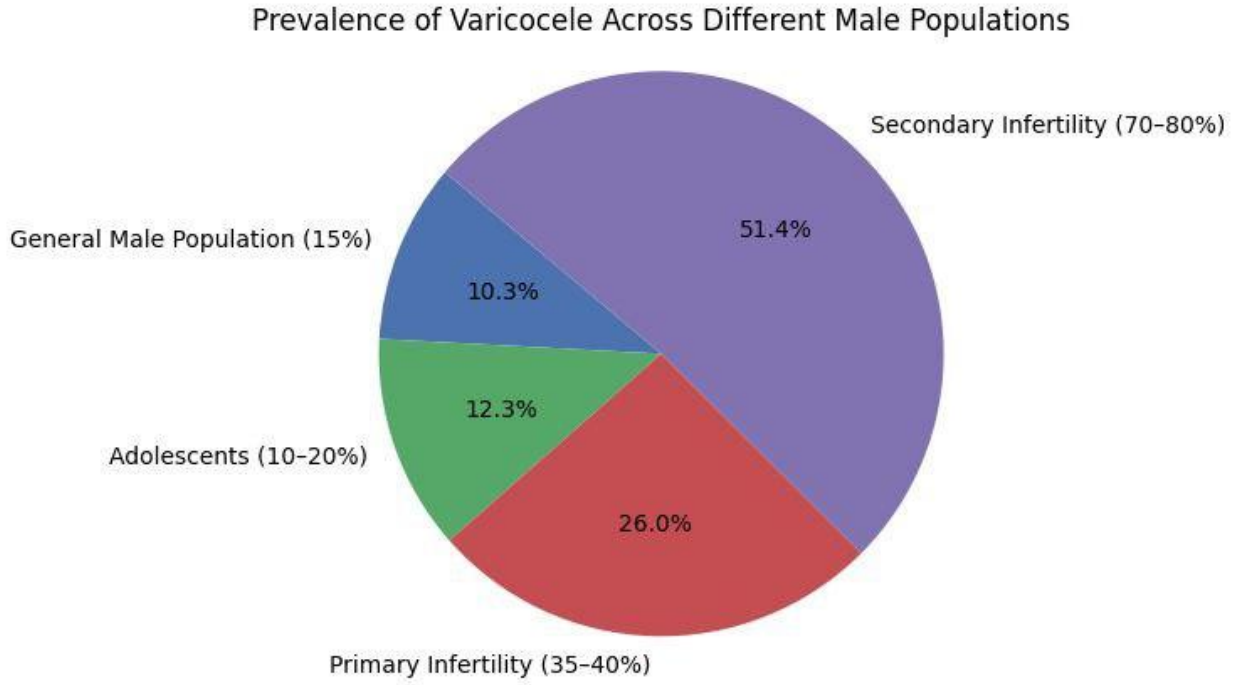

Figure 1. Prevalence distribution of varicocele across different male populations. The pie chart illustrates approximate prevalence rates in the general male population (15%), adolescents (10–20%), men with primary infertility (35–40%), and men with secondary infertility (70–80%). The data demonstrate a markedly higher prevalence among infertile

AMERICAN ACADEMIC PUBLISHER
INTERNATIONAL JOURNAL OF MEDICAL SCIENCES
ISSN NUMBER: 2692 - 5206 Volume 6. No 02. February ,2026

populations, particularly those with secondary infertility, supporting the progressive impact of varicocele on reproductive potential.

Semen analysis findings consistently show reduced sperm concentration, decreased motility, and abnormal morphology in men with clinically significant varicocele. Meta-analyses indicate that sperm concentration may be reduced by 20–30% compared with healthy controls. Elevated levels of sperm DNA fragmentation and oxidative stress markers have been documented, reinforcing the biological plausibility of varicocele-induced reproductive damage.

Hormonal evaluations reveal subtle endocrine alterations. While serum testosterone levels often remain within normal range, intratesticular testosterone may be reduced, and follicle-stimulating hormone levels can be mildly elevated in advanced cases. These changes reflect compensatory mechanisms responding to impaired spermatogenesis.

Doppler ultrasonography findings demonstrate that venous diameter greater than 3 mm combined with reflux lasting more than two seconds during Valsalva maneuver is strongly associated with clinically significant varicocele. Subclinical cases detected solely by imaging show less consistent correlation with semen abnormalities, highlighting the importance of clinical context.

Surgical correction, particularly microsurgical subinguinal varicocelectomy, has been associated with improvement in semen parameters in approximately 60–70% of treated men. Pregnancy rates following repair vary between 30% and 45% within one year, depending on female partner factors. In adolescents, catch-up growth of the affected testis occurs in 60–80% of cases following timely intervention.

Preventive strategies remain heterogeneous across healthcare systems. Some countries implement routine adolescent screening, while others rely on symptomatic presentation. Evidence suggests that structured follow-up of adolescents with significant testicular asymmetry reduces risk of long-term fertility impairment.

Overall, results indicate that varicocele exerts measurable negative effects on testicular development and semen quality in a subset of patients, though not all affected individuals experience infertility. Identifying high-risk cases remains a central clinical challenge.

Discussion: The findings of this review highlight the complex interplay between anatomical predisposition, physiological disruption, and reproductive outcomes in varicocele. The high prevalence during adolescence suggests that pubertal hemodynamic changes unmask latent venous insufficiency. However, the variability in progression underscores the heterogeneity of disease expression.

AMERICAN ACADEMIC PUBLISHER
INTERNATIONAL JOURNAL OF MEDICAL SCIENCES
ISSN NUMBER: 2692 - 5206 Volume 6. No 02. February ,2026

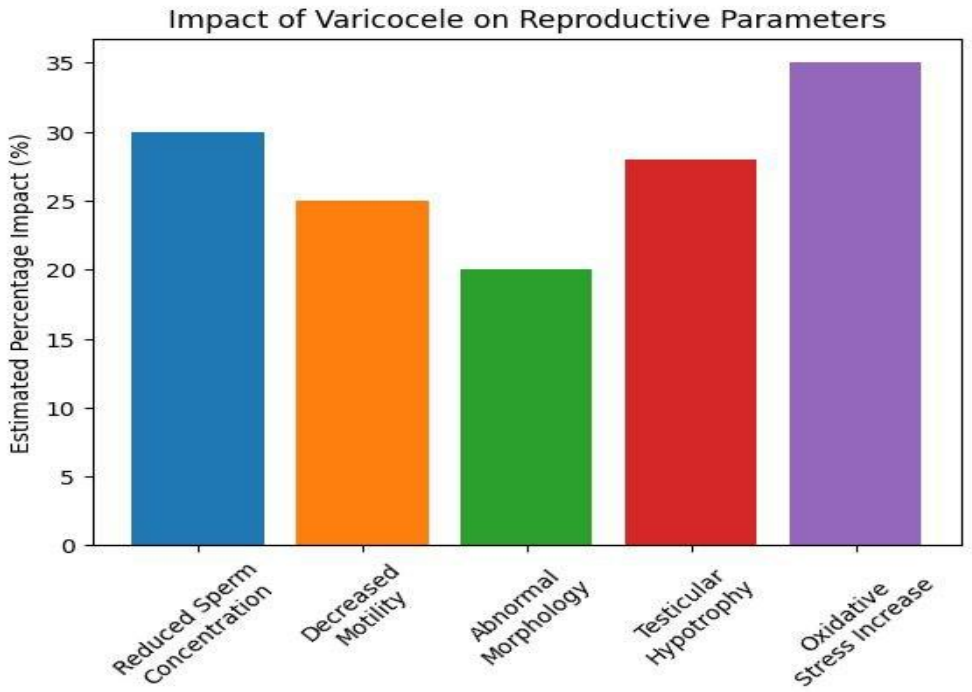

Figure 2. Impact of varicocele on key reproductive parameters. The bar chart presents estimated percentage reductions or pathological changes reported in the literature, including decreased sperm concentration, reduced motility, abnormal morphology, testicular hypotrophy, and increased oxidative stress. Oxidative stress appears to be one of the most prominent biological mechanisms underlying spermatogenic impairment.

From a pathophysiological standpoint, the convergence of hyperthermia, oxidative stress, and hypoxia creates a hostile microenvironment for spermatogenesis. The testes operate under tightly regulated thermal and metabolic conditions. Even minor deviations can disrupt meiotic processes and sperm maturation. Experimental models confirm that prolonged elevation in scrotal temperature induces germ cell apoptosis and reduces sperm count. Oxidative stress further exacerbates cellular damage by impairing mitochondrial function and increasing DNA fragmentation.

Yet, not all adolescents with varicocele develop fertility problems. Genetic susceptibility, antioxidant capacity, and duration of exposure likely influence outcomes. This variability complicates early intervention strategies. Universal surgical correction risks overtreatment, whereas conservative management may permit irreversible damage in high-risk individuals.

The debate surrounding screening reflects broader public health considerations. Routine adolescent screening may enable early identification of testicular asymmetry, but cost-effectiveness analyses remain limited. Psychological impact must also be considered, as labeling asymptomatic teenagers with a potential fertility risk may generate anxiety.

Advances in imaging technology offer improved diagnostic precision. Standardized ultrasonographic criteria reduce interobserver variability and enhance longitudinal monitoring. Incorporating testicular volume measurement and Doppler reflux assessment into routine evaluation improves risk stratification.

AMERICAN ACADEMIC PUBLISHER
INTERNATIONAL JOURNAL OF MEDICAL SCIENCES
ISSN NUMBER: 2692 - 5206 Volume 6. No 02. February ,2026

Surgical outcomes demonstrate meaningful improvement in semen parameters, yet pregnancy depends on multifactorial influences. Therefore, varicocelectomy should be individualized, particularly in adolescents where future fertility intentions are not immediate.

Preventive strategies should focus on structured follow-up programs rather than indiscriminate intervention. Adolescents with significant testicular asymmetry, persistent pain, or progressive deterioration warrant closer monitoring. Public health education targeting reproductive health awareness can reduce stigma and encourage early consultation.

Future research should prioritize long-term cohort studies tracking adolescents into adulthood to determine predictive markers of infertility. Biomarkers of oxidative stress and genetic profiling may refine risk assessment.

In summary, early detection and prevention of varicocele-related reproductive dysfunction require balanced clinical judgment, evidence-based guidelines, and patient-centered decision-making.

Conclusion: Varicocele remains a prevalent and clinically significant condition among adolescents and men of reproductive age. Although frequently asymptomatic, it can adversely affect testicular development and semen quality through mechanisms involving hyperthermia, oxidative stress, and impaired venous drainage. Epidemiological evidence confirms increased prevalence during puberty and strong association with male infertility in adulthood. Early detection poses both opportunity and challenge. While routine screening may facilitate timely identification of high-risk individuals, indiscriminate intervention risks overtreatment. Current evidence supports structured surveillance combined with individualized management based on testicular asymmetry, semen abnormalities, and symptom progression. Preventive strategies should prioritize education, standardized diagnostic criteria, and longitudinal follow-up programs. Surgical intervention demonstrates significant improvement in selected patients, particularly when performed before irreversible damage occurs. Ultimately, optimizing reproductive outcomes requires integration of clinical vigilance, scientific evidence, and public health awareness. A balanced approach to early detection and prevention can reduce future infertility burden while preserving quality of life in affected individuals.

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