

PGT-A在反复种植失败患者妊娠结局中的应用价值综述

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摘要

胚胎植入前遗传学筛查(PGT-A)是辅助生殖技术的重要组成部分, 它通过识别和排除染色体数目异常胚胎, 从而达到提升试管婴儿的妊娠成功率和活产率的效果, 近年来受到了广泛的关注。PGT-A技术不断进步, 但其临床应用效果及对妊娠结局的具体影响仍存在争议。本文基于大量最新临床研究和多中心随机对照试验, 系统评估了PGT-A在活产率、流产率、胚胎植入率及新生儿健康等关键结局指标上的表现, 深入分析了其优势与局限。旨在为临床医生提供科学的决策参考, 推动PGT-A技术的合理应用与优化, 促进辅助生殖领域的健康发展。

关键词

反复种植失败, 胚胎植入前遗传学筛查(PGT-A), 妊娠结局, 胚胎染色体异常, 辅助生殖技术

The Application Value of PGT-A in Pregnancy Outcome of Patients with Repeated Implantation Failure Was Reviewed

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Abstract

Preimplantation genetic screening (PGT-A) is an important part of assisted reproductive technology.

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It can improve the pregnancy success rate and live birth rate of IVF by identifying and excluding embryos with abnormal chromosome number, which has received extensive attention in recent years. PGT-A technology continues to progress, but its clinical application effect and specific impact on pregnancy outcomes are still controversial. Based on a large number of latest clinical studies and multi-center randomized controlled trials, this paper systematically evaluated the performance of PGT-A in key outcome indicators such as live birth rate, abortion rate, embryo implantation rate and neonatal health, and deeply analyzed its advantages and limitations. The aim is to provide scientific decision-making reference for clinicians, promote the rational application and optimization of PGT-A technology, and promote the healthy development of assisted reproduction.

Keywords

Repeated Planting Failure, Preimplantation Genetic Screening (PGT-A), Pregnancy Outcome, Embryo Chromosome Abnormalities, Assisted Reproductive Technology

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1. 前言

反复种植失败(Recurrent Implantation Failure, RIF)是指经过一定次数的胚胎移植后仍未获得妊娠的临床问题,在不同的文献报道中定义有所差别,最新临床共识是指胚胎移植至少3次未达到妊娠[1]。临床表现为多次优质胚胎移植没有发生妊娠,它会导致病人心理压力大,经济负担重,影响生活质量[2]。到目前为止,RIF的病因尚不清楚,包括胚胎质量问题、子宫内膜问题、免疫功能紊乱等原因,其中胚胎染色体异常是导致RIF的主要原因[3][4]。然而,对于无明显病理特征的RIF患者,它的具体发病机制还有待研究。这增加了治疗的不确定性[1]。

随着基因检测技术的发展,胚胎植入前遗传学检测(Preimplantation Genetic Testing, PGT)成为辅助生殖中筛查胚胎染色体异常的重要手段。PGT分为PGT-A(筛查胚胎染色体非整倍体)、PGT-M(单基因病检测)和PGT-SR(结构染色体异常检测)三大类[5]。其中,PGT-A就是我们常说的筛查非整倍体,是通过检测胚胎染色体数目异常来选择“单倍体”的胚胎进行移植,从而减少流产的风险并提高活产率[6][7]。PGT-A技术的目的是解决人类胚胎中存在的高比例的染色体异常的问题,这些问题被认为是导致胚胎发育失败和早期流产的主要原因[8][9]。现在临床利用高通量测序(NGS)等先进技术,能够对胚胎全基因组进行有效检测,提高检测的准确性和临床应用价值[10][11]。

胚胎植入前遗传学检测的技术优势在于可从遗传学角度准确甄别并挑选出无任何结构异常染色体的整倍体胚胎。该方法从胚胎选择层面调整单次移植胚胎数,可以从根本上提高单次移植的着床潜能,该方法的应用可以在大幅度提高累积活产率的同时有效地降低移植胚胎染色体异常所导致的自然流产率,并在很大程度上缩短了病患获得活产的时间周期。这一策略的临床价值在特定人群中尤为突出,例如因年龄增长导致胚胎非整倍体风险显著升高的高龄女性,以及饱受反复流产或反复种植失败困扰的患者[12][13]。既往临床研究表明:PGT-A可以明显提高部分患者的活产率及临床妊娠率,降低流产的发生[14][15]。例如,对于年龄较大的患者(≥ 35 岁),PGT-A有助于提高临床妊娠率和活产率[12][16]。同时,使用PGT-A可以给有平衡易位或某种染色体异常的夫妇选择染色体正常或平衡的胚胎,避免再次发生流产及出生缺陷[17][18]。

然而, PGT-A 在实际临床应用中仍存在许多待探讨的问题。首先, 即使检测了胚胎是否存在染色体异常, 也不能完全说明所有种植失败原因, 也就是说, “单倍体”胚胎仍有其自身“单倍体”的因素而导致此胚胎不能发生正常的种植[7] [19]。其次, PGT-A 技术本身存在一定的误差, 如染色体嵌合体(mosaicism)的存在, 无法确定该胚胎是否是真正的异常, 可能导致健康胚胎被误判为异常而被弃用[6] [20]。此外, PGT-A 的费用较高, 且存在侵入性取样, 可能对胚胎造成潜在损伤[10] [21]。部分研究也指出, PGT-A 在年轻的患者或者没有任何高风险因素的患者上面, 是没有显著提高她们的活产率的, 甚至会使得 PGT 的周期变得更加长, 从而造成患者额外的心理压力[22] [23]。

对于 PGT-A 在 RIF 患者中应用的研究结果存在一定的争议。部分学者认为, PGT-A 可以降低 RIF 患者胚胎染色体异常率, 提高移植成功率及妊娠结局[1]-[3] [24]。例如, NGS 技术下的 PGT-A 在 RIF 患者中显示出较高的胚胎单倍体率, 并显著提升临床妊娠率和活产率[4] [25]。此外, 结合子宫内膜容受性检测(ERA), 使用 ERA 指导 PGT-A 结合个性化移植技术在 RIF 患者中的应用可获得更佳妊娠结局[26] [27]。但也有研究指出, 对于年龄较轻的 RIF 患者, PGT-A 并未显著提升活产率, 因此患者的适用范围可能还有待考虑[19] [28]。此外, 目前 PGT-A 的临床效度还受样本量、研究设计、患者个体差异的限制, 仍需更多的大样本、多中心、随机对照实验来进行验证[29] [30]。

综上所述, 反复种植失败(RIF)的病理机制较为复杂, 其中影响反复种植失败最主要的因素为胚胎染色体非整倍体。而胚胎植入前遗传学检测技术可发现胚胎的染色体异常, 并根据胚胎的染色体情况, 选择更优质的胚胎移植至宫腔内, 从而实现改善 RIF 患者的妊娠结局的目的。PGT-A 在辅助生殖领域的演进及其在染色体筛查中的核心应用, 为提升治疗成功率奠定了坚实的遗传学基础。然而, 目前 PGT-A 在 RIF 患者中的应用结果还有待于讨论, 应加强相关系统综述以及高质量的研究, 进而判定其在不同患者群体中的临床价值与应用边线, 为临床的抉择提供强有力的证据支撑。

2. 主体

2.1. PGT-A 技术原理及发展现状

2.1.1. PGT-A 的技术流程及检测方法

在 PGT-A 技术流程中, 胚胎活检是决定是否妊娠的关键, 其本质上是在诊断时效性与最大程度保证胚胎安全性之间进行权衡。经典的第 3 天卵裂期活检, 其优点就是可以在早期获得遗传学诊断结果, 而且可以选择新鲜胚胎移植, 这也正是该方法最主要的临床优势之一, 但是这种方法也有无法避免的缺点, 由于是从只有几个细胞的胚胎上取出, 其代表性无法判断, 因而可能会影响诊断结果的准确性; 而且对于如此早的胚胎采取这样一种剧烈的物理操作, 势必会对胚胎正常的发育过程造成一定的损伤, 从而影响最后的种植率。囊胚期活检则是在第 5~6 天胚胎形成囊胚时, 从 TE 层采集 5~6 个细胞, 样本量相对充足, 更具有代表性, 且囊胚活检对胚胎潜能影响较小, 检测准确性更高[31] [32]。因此, 囊胚期活检已成为 PGT-A 主流方式。

染色体异常检测技术的迭代升级, 是推动 PGT-A 发展的核心驱动力。最早的检测方式是荧光原位杂交(FISH), 该方法受其原理所限, 仅能对少数几条染色体进行分析, 因此在检测完整性和精确性上有天然缺陷。随后, 阵列比较基因组杂交(aCGH)与单核苷酸多态性(SNP)芯片技术的引入, 彻底改变了这一局面, 它们突破了 FISH 的靶向性限制, 能够一次性覆盖所有染色体的拷贝数变化, 实现了从“点”到“面”的检测模式转变。这一变革极大地拓宽了检测的广度与深度, 为胚胎的精准遗传学评估奠定了更为坚实的技术基石[33] [34]。目前, 随着 NGS 技术的发展, 在 PGT-A 领域已广泛应用, 能实现一次覆盖全基因组染色体拷贝数变异的高通量检测, 并具有良好的敏感性和特异性, 可与其他检测方法(如 PGT-M、PGT-

SR)联合检测,更具有综合性[35]-[37]。例如,基于 NGS 的 OnePGT 和 KaryoSeq 平台均实现了 PGT-M、PGT-A 和 PGT-SR 的联合检测,费用和时间效率得到优化[35] [36]。

数据解读环节将数据通过染色体拷贝数分析、单体型推断和杂合度分析进行解读,并根据胚胎活检细胞的遗传信息,完成胚胎染色体异常筛查及胚胎筛选。技术准确性受限于全基因组扩增(WGA)偏好性扩增、等位基因缺失(ADO)、生物学杂合度和胚胎内细胞遗传多样性(如嵌合体)等因素[38] [39]。此外,假阴性和假阳性也是 PGT-A 结果解读的重要误差来源,特别是对于嵌合体胚胎来说判定更加困难。目前已经有最新的报道证明,通过严格规定嵌合体阈值(如异常细胞比例 30%~70%)可减少假阳性,提高整体诊断准确率[39]。因此,合理的诊断阈值和严谨的数据分析算法是保障 PGT-A 技术可靠性的关键。

2.1.2. PGT-A 技术的临床应用范围及限制

PGT-A 主要适用于辅助生殖中需提高胚胎植入率、降低流产率和遗传异常风险的患者,特别是高龄患者、反复种植失败(RIF)患者及反复流产患者[40]-[42]。研究显示,PGT-A 可显著提高高龄患者和 RIF 患者的临床妊娠率和活产率,减少移植周期数[27] [42]。此外,将 PGT-A 与个性化子宫内膜容受性分析(ERA)结合使胚胎移植更有针对性,有利于提高临床结局[27]。PGT-A 还可以用于遗传病携带者筛查、结构染色体异常患者的辅助生殖治疗[43] [44]。

然而,PGT-A 存在技术局限。首先,胚胎活检为侵入性操作,尽管囊胚期活检对胚胎潜能的影响较小,但仍存在一定风险[45]。其次,PGT-A 无法准确判断检测出的胚胎内部的遗传异质性(嵌合体)是否出现异常,易出现假阴性或假阳性的结果,因此容易造成正常胚胎错误剔除或异常胚胎错误选择的风险,影响临床效果[39] [46]。第三,PGT-A 需配合高质量的活检样本和扩增技术,技术操作复杂,费用较高,不适合所有患者广泛应用[36] [47]。此外,多胚胎移植策略和多胎妊娠风险也为 PGT-A 的实际应用带来挑战[48]。伦理和法律问题方面,PGT-A 涉及胚胎选择,存在胚胎命运、隐私保护、知情同意和公平性一系列伦理争议[49] [50]。不同国家和地区对 PGT-A 的法规和伦理规范存在差异,要结合当地的国情和法律法规出台适合当地的法律法规[51] [52]。

2.2. PGT-A 对反复种植失败患者临床结局的影响

2.2.1. 妊娠率和活产率的改善

反复种植失败(RIF)患者的妊娠率、活产率是评判辅助生殖技术效果的核心指标,多项临床研究及荟萃分析表明,通过 PGT-A 技术筛选出染色体正常的胚胎,能够有效提高 RIF 患者的妊娠率和活产率。Tang 等人的回顾性研究指出,对于不明原因的反复流产(iRPL)患者,使用基于 NGS 的 PGT-A 相较于传统 IVF/ICSI,移植胚胎的植入率、临床妊娠率及活产率均显著提高(植入率 64.2% vs 38.2%,临床妊娠率 57.5% vs 33.3%,活产率 45% vs 28.4%,均 $p < 0.05$),但是这种优势仅见于年龄 ≥ 35 岁的患者,年龄较小者两者间差异不大[3]。另一项涉及 253 个 RIF 周期的研究发现,纯冻胚移植(FET)联合 PGT-A 组的生化妊娠率和临床妊娠率均显著高于未进行 PGT-A 的对照组(生化妊娠率 OR = 5.5,临床妊娠率 OR = 2.3,均 $p < 0.05$),而仅进行子宫内膜容受性分析(ERA)的组别未见显著改善[53]。

此外,针对年龄较大的 RIF 患者而言,使用 NGS 技术的 PGT-A 同样获得了临床妊娠率和植入率的提升。Zhang 等人的研究中,年龄 ≥ 38 岁的 RIF 患者 PGT-A 组胚胎的植入率明显优于非 PGT-A 组(39.1% vs 51.0%),提示胚胎异常是 RIF 的重要因素,而年龄对筛选出的单倍体胚胎的植入潜能几乎没有影响[4]。尽管如此,部分研究也指出,PGT-A 并不能改善严重的 RIF 患者的结果,这说明患者的病因以及其严重程度均会影响 PGT-A 的疗效[54]。

综上所述,PGT-A 通过筛选染色体正常的胚胎,能够有效提升 RIF 患者的妊娠率和活产率,且年龄

较大患者受益更为明显。不同文献之间存在的差异可能是由于患者的人群组成、PGT-A 的手段以及移植方式、内膜的状态等各种不同的因素,临床上还需要结合患者的实际情况来进行具体的治疗。

2.2.2. 流产率和胚胎停育的降低

胚胎染色体异常是流产和胚胎停育的主要原因之一,尤其是在反复流产和反复种植失败患者中尤为突出。PGT-A 通过剔除染色体异常胚胎,显著降低了流产和胚胎停育的风险。多项临床数据支持 PGT-A 在减少流产率方面有积极作用。

例如,一项针对不明原因反复流产患者的研究显示,PGT-A 组流产率明显低于非 PGT-A 组,尤其是在高龄患者中效果更为显著[55]。另有研究表明,PGT-A 可将早期妊娠丢失率从传统方法中的 37.93%降低至 17.07%[56]。此外,针对 RIF 患者,PGT-A 显著降低了临床妊娠后的流产率的同时,还可以提高活产率[57]。

综上所述,PGT-A 能提高胚胎种植率、临床妊娠率等,还能降低患者的焦虑情绪,缩短了患者的治疗周期,可以更好地节约经济成本[3]。未来对 PGT-A 的大样本、多中心的成本效益及心理影响的评价,可指导其临床合理应用。

2.2.3. 其他临床结局指标的评估

除妊娠率、活产率和流产率外,PGT-A 对其他临床指标也表现出积极影响。多个研究报道 PGT-A 显著提高胚胎植入率,减少多胎妊娠率,并降低治疗周期所需的胚胎移植次数。例如,PGT-A 组中胚胎植入率可达到 41.5%,显著高于非 PGT-A 组的 16.2% [25] [58]。此外,由于筛选出高质染色体正常胚胎,PGT-A 减少了多胎妊娠率和流产风险,提高了治疗的安全性。

心理压力方面,反复种植失败患者往往承受较大心理负担。PGT-A 能够提高成功率,缩短达到妊娠的时间,这样一来可以明显减轻患者身体和心理压力[3] [59]。一项针对 PGT 用户的质性研究指出,患者想要得到更多的失败期的心理支持与疏导,所以临床需要考虑并重视患者的心理需求,完善咨询[59]。

从经济成本效益角度看,虽然 PGT-A 初期投入较大,但可大大减少移植次数以及流产率,节省移植周期,缩减治疗过程中的医疗费用,所以长期成本效益较好。一项基于倾向匹配的研究显示,PGT-A 能显著缩短治疗周期(平均缩短约两个月),减少流产,提升治疗效率,成本效益尤为明显[58]。但这与患者的年龄、胚胎数量和个体情况有关,不可一概而论。

2.3. PGT-A 对新生儿健康及长期结局的影响

PGT-A 对于新生儿出生体重的影响没有定论。有文献报道 PGT-A 组新生儿出生体重与对照组没有明显的差异性[60],而在特定卵巢刺激方案下,PGT-A 组良好胚胎的数量及质量可能较低,提示可能间接影响出生体重[61]。关于先天缺陷发生率问题,多项研究证实了 PGT-A 组和传统辅助生殖组发生先天缺陷的比例并没有显著差异,且 PGT-SR (结构重排筛查)有助于降低因染色体异常引起的胎儿畸形风险[62] [63]。此外,双重胚胎活检虽可能降低活产率,但不会对新生儿出生体重及性别比例产生负面影响[64]。

通过 PGT-A 技术辅助的妊娠儿童远期的健康状况及发育情况是临床较为关心的问题。目前仅有少量的研究报道,并且均为来自注册数据库或随访队列的数据,但结果都比较积极。一项涵盖瑞典 390 例 PGT 单胎儿的全国性注册研究对比了 PGT 与传统 IVF/ICSI 及自然妊娠儿童的早期健康结局,发现 PGT 儿童的早产率、低出生体重率及先天畸形的发生率与 IVF-ICSI 及自然妊娠儿相似,免疫相关疾病如哮喘、过敏等的发病情况无明显差异,也无死亡病例报导[65]。尽管随访时间有限(平均约 4.6 年),该研究为 PGT 儿童的安全性提供了初步证据。

未来研究需重点关注 PGT 儿童的神经发育、免疫功能、代谢健康和心理行为表现,并且需要建立多

中心、长时程随访队列,根据遗传、环境等因素综合分析儿童健康的多方面指标[66]。同时,应加强对 PGT 技术的安全性监测,优化活检策略和遗传检测技术,从而保障儿童长期健康。总之,目前的数据表明 PGT-A 儿童在短期内是相对安全的,但是还是需要加强后续的随访,进行更深入的研究来全面评估 PGT-A 儿童的长期安全性以及可能带来的风险[65]。

3. 结论

随着辅助生殖技术的发展,RIF 作为一种复杂的,涉及多因素作用的临床问题逐渐引起了广大学者、临床工作者的重视。通过对相关文献资料进行总结可知,未来针对 RIF 领域的研究需要将重点放在制定统一诊断标准、选择最合适的诊治手段及打破传统的壁垒、推动各学科的联合上。这样才能更有效地提升患者的临床结局。

首先,统一且科学的 RIF 诊断标准是推动其领域内开展相关研究工作、指导实践应用的基础,目前因 RIF 尚无明确统一的标准,从而造成一些已报道的结果无法互相比,影响推广与应用,在今后的 RIF 研究中应根据患者的不同病因分层分别进行分析,以提高精准性和验证不同病因是否具有不同的发病机理以及不同的治疗反应;同时增加标尺化,规范标准化,有利于将来积累大量的循证医学资料,促进临床路径优化。

其次,前瞻性比较研究在新技术验证中扮演着重要角色。以无创胚胎基因检测(niPGT-A)与传统活检技术的比较为例,尽管初步研究显示 niPGT-A 具有更低的胚胎损伤及更高的检测安全系数,但没有证据证明其具有实际的临床功效与长期的安全性。因此应通过设计高含量偏析的前瞻性的 RCT,去比较两者的妊娠率、活产率以及并发症发生率,从而支持新技术的应用。这样可以避免由于使用新技术所带来的不必要的损失以及造成医疗资源浪费的风险。

第三,人工智能(AI)技术的引入为胚胎筛选和 RIF 治疗带来了前所未有的机遇。通过将基因组学、形态学和代谢组学信息融为一体来建立更加精准的胚胎预测模型,可以实现在胚胎的质量判别及后续的移植决策上作出更加合理的决定,并能挖掘出更多的致病原因以及治疗靶点;日后基于大数据、机器学习的智能化辅助诊疗,会成为辅助生殖领域重要的诊疗工具,实现个性化医疗。

最后,多学科交叉融合以及高质量的临床研究均能促进 RIF 理论创新与临床实践的进步,生殖医学、遗传学、免疫学及数据科学的强强联合将为 RIF 的病因、治疗等相关研究带来新的思考方向,而高质量的临床试验不仅可以证明新疗法的有效性,还能揭示不同治疗方案的适应症和副作用,为临床决策提供科学依据。通过这种协同创新,最终目标是实现患者生育结局的显著改善,帮助更多家庭实现生育愿望。

综上所述,未来 RIF 领域发展需要建立标准化诊断的基础之上,运用新技术的科学证明,充分应用人工智能的强大潜力,同时要利用多学科的合作,结合高质量的临床研究,才能够真正地突破瓶颈,实现更加精准、高效的辅助生殖技术走向临床的突破,造福广大患者。这一进程既需要科研人员的持续努力,也需临床实践的不断反馈和优化,为实现个体化生殖健康管理奠定坚实基础。

参考文献

- [1] Fu, M., Zhang, X., Liang, Y., Lin, S., Qian, W. and Fan, S. (2020) Alterations in Vaginal Microbiota and Associated Metabolome in Women with Recurrent Implantation Failure. *mBio*, **11**, e03242-19. <https://doi.org/10.1128/mbio.03242-19>
- [2] Guo, Y., Tang, B., Zhang, L., Wu, X. and Huang, Z. (2025) Anxiety and Depression in Recurrent Implantation Failure after Frozen-Thawed Embryo Transfer and Efficacy of Endometrial Receptivity Testing. *World Journal of Psychiatry*, **15**, Article 109175. <https://doi.org/10.5498/wjp.v15.i9.109175>
- [3] Shi, X., Tang, Y., Liu, C., Li, W., Lin, H., Mao, W., et al. (2023) Effects of NGS-Based PGT-A for Idiopathic Recurrent Pregnancy Loss and Implantation Failure: A Retrospective Cohort Study. *Systems Biology in Reproductive Medicine*, **69**,

- 354-365. <https://doi.org/10.1080/19396368.2023.2225679>
- [4] Tong, J., Niu, Y., Wan, A. and Zhang, T. (2021) Next-Generation Sequencing (NGS)-Based Preimplantation Genetic Testing for Aneuploidy (PGT-A) of Trophoctoderm Biopsy for Recurrent Implantation Failure (RIF) Patients: A Retrospective Study. *Reproductive Sciences*, **28**, 1923-1929. <https://doi.org/10.1007/s43032-021-00519-0>
 - [5] Tian, Y., Li, M., Yang, J., Chen, H. and Lu, D. (2024) Preimplantation Genetic Testing in the Current Era, a Review. *Archives of Gynecology and Obstetrics*, **309**, 1787-1799. <https://doi.org/10.1007/s00404-024-07370-z>
 - [6] Tikhonov, A.V., Krapivin, M.I., Malysheva, O.V., Komarova, E.M., Golubeva, A.V., Efimova, O.A., *et al.* (2024) Re-examination of PGT-A Detected Genetic Pathology in Compartments of Human Blastocysts: A Series of 23 Cases. *Journal of Clinical Medicine*, **13**, Article 3289. <https://doi.org/10.3390/jcm13113289>
 - [7] Cimadomo, D., Rienzi, L., Conforti, A., Forman, E., Canosa, S., Innocenti, F., *et al.* (2023) Opening the Black Box: Why Do Euploid Blastocysts Fail to Implant? A Systematic Review and Meta-Analysis. *Human Reproduction Update*, **29**, 570-633. <https://doi.org/10.1093/humupd/dmad010>
 - [8] Liu, X., Fan, Q., Wang, J., Li, R., Xu, Y., Guo, J., *et al.* (2020) Higher Chromosomal Abnormality Rate in Blastocysts from Young Patients with Idiopathic Recurrent Pregnancy Loss. *Fertility and Sterility*, **113**, 853-864. <https://doi.org/10.1016/j.fertnstert.2019.11.016>
 - [9] Viotti, M. (2020) Preimplantation Genetic Testing for Chromosomal Abnormalities: Aneuploidy, Mosaicism, and Structural Rearrangements. *Genes*, **11**, Article 602. <https://doi.org/10.3390/genes11060602>
 - [10] Doroftei, B., Ilie, O., Anton, N., Armeanu, T. and Ilea, C. (2022) A Mini-Review Regarding the Clinical Outcomes of in Vitro Fertilization (IVF) Following Pre-Implantation Genetic Testing (PGT)-Next Generation Sequencing (NGS) Approach. *Diagnostics*, **12**, Article 1911. <https://doi.org/10.3390/diagnostics12081911>
 - [11] Niu, W., Dai, S., Hu, L., He, Y., Zhang, X., Xue, X., *et al.* (2025) Chrominst: A Multicentre Evaluation of Robustness in Aneuploidy and Structural Rearrangement Testing. *Journal of Translational Medicine*, **23**, Article No. 230. <https://doi.org/10.1186/s12967-025-06242-7>
 - [12] Adamyan, L., Pivazyanyan, L., Obosyan, L., Krylova, E. and Isaeva, S. (2024) Preimplantation Genetic Testing for Aneuploidy in Patients of Different Age: A Systematic Review and Meta-Analysis. *Obstetrics & Gynecology Science*, **67**, 356-379. <https://doi.org/10.5468/ogs.24028>
 - [13] Luo, S., Li, X., Wang, Y., *et al.* (2024) Effect of Preimplantation Genetic Testing for Aneuploidies on Live Birth Outcomes and the Influencing Factors in Women of Advanced Maternal Age. *Journal of Sichuan University (Medical Science Edition)*, **55**, 1288-1294.
 - [14] Moini, A., Najafpour, N., Kashani, L., Farid-Mojtahedi, M., Maleki-Hajiagha, A., Tehranian, A., *et al.* (2024) Outcomes of Female Reproductive Performance with Assisted Reproductive Techniques after Recent Mild to Moderate COVID-19 Infections: An Observational Study. *Clinical and Experimental Reproductive Medicine*, **51**, 268-275. <https://doi.org/10.5653/cerm.2023.06352>
 - [15] Kim, J.W., Lee, S.Y., Hur, C.Y., Lim, J.H. and Park, C.K. (2024) Clinical Outcomes of Preimplantation Genetic Testing for Aneuploidy in High-Risk Patients: A Retrospective Cohort Study. *Clinical and Experimental Reproductive Medicine*, **51**, 75-84. <https://doi.org/10.5653/cerm.2023.06394>
 - [16] Wang, S.F. and Seifer, D.B. (2025) Comparative Age-Stratified Analysis of Live-Birth Outcomes in Primary Embryo Transfer to Assess the Effect of Preimplantation Genetic Testing for Aneuploidy. *Obstetrics & Gynecology*, **146**, 898-906. <https://doi.org/10.1097/aog.0000000000006047>
 - [17] Shetty, S., Nair, J., Johnson, J., Shetty, N., Kumar J. A., Thondehalmath, N., *et al.* (2022) Preimplantation Genetic Testing for Couples with Balanced Chromosomal Rearrangements. *Journal of Reproduction & Infertility*, **23**, 213-223. <https://doi.org/10.18502/jri.v23i3.10013>
 - [18] Zhou, F., Ren, J., Li, Y., Keqie, Y., Peng, C., Chen, H., *et al.* (2024) Preimplantation Genetic Testing in Couples with Balanced Chromosome Rearrangement: A Four-Year Period Real World Retrospective Cohort Study. *BMC Pregnancy and Childbirth*, **24**, Article No. 86. <https://doi.org/10.1186/s12884-023-06237-6>
 - [19] Du, Y., Guan, Y., Li, N., Shi, C., Zhang, Y., Ren, B., *et al.* (2023) Is It Necessary for Young Patients with Recurrent Implantation Failure to Undergo Preimplantation Genetic Testing for Aneuploidy? *Frontiers in Endocrinology*, **14**, Article ID: 1020055. <https://doi.org/10.3389/fendo.2023.1020055>
 - [20] Popa, T., Davis, C., Xanthopoulou, L., Bakosi, E., He, C., O'Neill, H., *et al.* (2025) Current Quantitative Methodologies for Preimplantation Genetic Testing Frequently Misclassify Meiotic Aneuploidies as Mosaic. *Fertility and Sterility*, **124**, 307-318. <https://doi.org/10.1016/j.fertnstert.2025.02.018>
 - [21] Poli, M., Picchetta, L., Siciliani, L. and Capalbo, A. (2025) Evidence-Based Reporting in Preimplantation Genetic Testing (PGT). *Genes*, **16**, Article 1083. <https://doi.org/10.3390/genes16091083>
 - [22] Gleicher, N., Barad, D.H., Patrizio, P., Gayete-Lafuente, S., Weghofer, A., Rafael, Z.B., *et al.* (2024) An Additive Opinion to the Committee Opinion of ASRM and SART on the Use of Preimplantation Genetic Testing for Aneuploidy (PGT-

- A). *Journal of Assisted Reproduction and Genetics*, **42**, 71-80. <https://doi.org/10.1007/s10815-024-03318-z>
- [23] Pacu, I., Zygouropoulos, N., Zampieri, G., Petca, A., Poenaru, M.O. and Ionescu, C.A. (2024) Effect of Treatment with Progestins and Antiplatelet Agents on IVF in Women with Adenomyosis and Recurrent Implantation Failure. *Diagnostics*, **15**, Article 30. <https://doi.org/10.3390/diagnostics15010030>
- [24] Kato, K., Ezoe, K., Onogi, S., Ito, S., Egawa, R., Aoyama, N., *et al.* (2023) Comparison of 1-Year Cumulative Live Birth and Perinatal Outcomes Following Single Blastocyst Transfer with or without Preimplantation Genetic Testing for Aneuploidy: A Propensity Score-Matched Study. *Journal of Assisted Reproduction and Genetics*, **40**, 2669-2680. <https://doi.org/10.1007/s10815-023-02926-5>
- [25] Pathak, A., Singh, P., Singh, P. and Desai, M. (2022) Selecting Euploid Embryos for Transfer by Preimplantation Genetic Testing with the Help of Next-Generation Sequencing in Poor Prognosis Patients: A Retrospective Cohort Analysis. *Journal of Human Reproductive Sciences*, **15**, 157-162. https://doi.org/10.4103/jhrs.jhrs_166_21
- [26] Amin, J., Patel, R., JayeshAmin, G., Gomedhikam, J., Surakala, S. and Kota, M. (2022) Personalized Embryo Transfer Outcomes in Recurrent Implantation Failure Patients Following Endometrial Receptivity Array with Pre-Implantation Genetic Testing. *Cureus*, **14**, e26248. <https://doi.org/10.7759/cureus.26248>
- [27] Barbakadze, T., Shervashidze, M., Charkviani, T., Zhorzholadze, T., Kbilashvili, T., Gabadze, M., *et al.* (2024) Assessment of the Role of Endometrial Receptivity Analysis in Enhancing Assisted Reproductive Technology Outcomes for Advanced-Age Patients. *Cureus*, **16**, e62949. <https://doi.org/10.7759/cureus.62949>
- [28] Guan, H., He, Y., Lu, Y., Huang, J., Wang, Y., Zhu, Q., *et al.* (2024) Effect of Preimplantation Genetic Testing for Aneuploidy on Live Birth Rate in Young Women with Recurrent Implantation Failure: A Secondary Analysis of a Multicentre Randomised Trial. *BJOG: An International Journal of Obstetrics & Gynaecology*, **132**, 92-99. <https://doi.org/10.1111/1471-0528.18027>
- [29] Genest, G., Liu, Z., Boivin, M., Alvarez, F., Banjar, S., Ton-leclerc, S., *et al.* (2025) Intravenous Immunoglobulin (IVIg) Use in Recurrent Implantation Failure: Is It Time for Another Randomized Controlled Trial? *Journal of Reproductive Immunology*, **171**, Article 104634. <https://doi.org/10.1016/j.jri.2025.104634>
- [30] Roberts, S.A., Wilkinson, J., Vail, A. and Brison, D.R. (2022) Does PGT-A Improve Assisted Reproduction Treatment Success Rates: What Can the UK Register Data Tell Us? *Journal of Assisted Reproduction and Genetics*, **39**, 2547-2554. <https://doi.org/10.1007/s10815-022-02612-y>
- [31] del Arco de la Paz, A., Giménez-Rodríguez, C., Selntigia, A., Meseguer, M. and Galliano, D. (2024) Advancements and Challenges in Preimplantation Genetic Testing for Aneuploidies: In the Pathway to Non-Invasive Techniques. *Genes*, **15**, Article 1613. <https://doi.org/10.3390/genes15121613>
- [32] Yang, H., Yang, D., Zhu, Q., Wang, K., Zhang, C., Chen, B., *et al.* (2022) Application of Two Blastocyst Biopsy Strategies in Preimplantation Genetic Testing Treatment and Assessment of Their Effects. *Frontiers in Endocrinology*, **13**, Article ID: 852620. <https://doi.org/10.3389/fendo.2022.852620>
- [33] Schmutzler, A.G. (2019) Theory and Practice of Preimplantation Genetic Screening (PGS). *European Journal of Medical Genetics*, **62**, Article 103670. <https://doi.org/10.1016/j.ejmg.2019.103670>
- [34] Coonen, E., Rubio, C., Christopikou, D., Dimitriadou, E., Gontar, J., Goossens, V., *et al.* (2020) ESHRE PGT Consortium Good Practice Recommendations for the Detection of Structural and Numerical Chromosomal Aberrations. *Human Reproduction Open*, **2020**, hoaa017. <https://doi.org/10.1093/hropen/hoaa017>
- [35] Masset, H., Zamani Esteki, M., Dimitriadou, E., Dreesen, J., Debrock, S., Derhaag, J., *et al.* (2019) Multi-Centre Evaluation of a Comprehensive Preimplantation Genetic Test through Haplotyping-by-Sequencing. *Human Reproduction*, **34**, 1608-1619. <https://doi.org/10.1093/humrep/dez106>
- [36] Li, S., Chang, C., Bai, H., Qian, W., Zou, Y., Wu, D., *et al.* (2025) A Novel and Comprehensive Whole-Genome Sequencing—Based Preimplantation Genetic Testing Approach for Different Genetic Conditions. *The Journal of Molecular Diagnostics*, **27**, 395-404. <https://doi.org/10.1016/j.jmoldx.2025.02.002>
- [37] Mai, A.D., Harton, G.L., Quang, V.N., Van, H.N., Thi, N.H., Thuy, N.P., *et al.* (2020) Development and Clinical Application of a Preimplantation Genetic Testing for Monogenic Disease (PGT-M) for Beta Thalassemia in Vietnam. *Journal of Assisted Reproduction and Genetics*, **38**, 365-374. <https://doi.org/10.1007/s10815-020-02006-y>
- [38] Unsal, E., Ozer, L., Baltaci, V., Duman, T., Halicigil, C., Koc, Z., *et al.* (2025) Assessing the Efficacy of Targeted Enrichment Protocol in PGT-M Applications: A Comprehensive Analysis. *Journal of Assisted Reproduction and Genetics*, **42**, 3829-3838. <https://doi.org/10.1007/s10815-025-03676-2>
- [39] Girardi, L., Figliuzzi, M., Poli, M., Serdarogullari, M., Patassini, C., Caroselli, S., *et al.* (2023) The Use of Copy Number Loads to Designate Mosaicism in Blastocyst Stage PGT-A Cycles: Fewer Is Better. *Human Reproduction*, **38**, 982-991. <https://doi.org/10.1093/humrep/dead049>
- [40] Capalbo, A., de Wert, G., Mertes, H., Klausner, L., Coonen, E., Spinella, F., *et al.* (2024) Screening Embryos for Polygenic Disease Risk: A Review of Epidemiological, Clinical, and Ethical Considerations. *Human Reproduction Update*,

- 30, 529-557. <https://doi.org/10.1093/humupd/dmae012>
- [41] Liang, Z., Wen, Q., Li, J., Zeng, D. and Huang, P. (2023) A Systematic Review and Meta-Analysis: Clinical Outcomes of Recurrent Pregnancy Failure Resulting from Preimplantation Genetic Testing for Aneuploidy. *Frontiers in Endocrinology*, **14**, Article ID: 1178294. <https://doi.org/10.3389/fendo.2023.1178294>
 - [42] Wang, S., Liu, L., Ma, M., Wang, H., Han, Y., Guo, X., *et al.* (2023) Preimplantation Genetic Testing for Aneuploidy Helps to Achieve a Live Birth with Fewer Transfer Cycles for the Blastocyst FET Patients with Unexplained Recurrent Implantation Failure. *Archives of Gynecology and Obstetrics*, **308**, 599-610. <https://doi.org/10.1007/s00404-023-07041-5>
 - [43] Shao, Y., Li, J., Lu, J., Li, H., Zhu, Y., Jiang, W., *et al.* (2020) Clinical Outcomes of Preimplantation Genetic Testing (PGT) Application in Couples with Chromosomal Inversion, a Study in the Chinese Han Population. *Reproductive Biology and Endocrinology*, **18**, Article No. 79. <https://doi.org/10.1186/s12958-020-00635-7>
 - [44] Kakourou, G., Vrettou, C., Mamas, T. and Traeger-Synodinos, J. (2025) Reproductive Choices in Haemoglobinopathies: The Role of Preimplantation Genetic Testing. *Genes*, **16**, Article 360. <https://doi.org/10.3390/genes16040360>
 - [45] Vljakovic, T., Grigore, M., van Eekelen, R. and Puscasiu, L. (2022) Day 5 versus Day 3 Embryo Biopsy for Preimplantation Genetic Testing for Monogenic/Single Gene Defects. *Cochrane Database of Systematic Reviews*, No. 11, CD013233. <https://doi.org/10.1002/14651858.cd013233.pub2>
 - [46] Xiao, M., Lei, C., Xi, Y., Lu, Y., Wu, J., Li, X., *et al.* (2021) Next-Generation Sequencing Is More Efficient at Detecting Mosaic Embryos and Improving Pregnancy Outcomes than Single-Nucleotide Polymorphism Array Analysis. *The Journal of Molecular Diagnostics*, **23**, 710-718. <https://doi.org/10.1016/j.jmoldx.2021.02.011>
 - [47] Niu, W., Wang, L., Xu, J., Li, Y., Shi, H., Li, G., *et al.* (2020) Improved Clinical Outcomes of Preimplantation Genetic Testing for Aneuploidy Using MALBAC-NGS Compared with MDA-SNP Array. *BMC Pregnancy and Childbirth*, **20**, Article No. 388. <https://doi.org/10.1186/s12884-020-03082-9>
 - [48] Shaia, K., Truong, T., Pieper, C. and Steiner, A. (2020) Pre-Implantation Genetic Testing Alters the Sex Ratio: An Analysis of 91,805 Embryo Transfer Cycles. *Journal of Assisted Reproduction and Genetics*, **37**, 1117-1122. <https://doi.org/10.1007/s10815-020-01746-1>
 - [49] Chan, S.H.S., Li, R.H.W., Lee, V.C.Y., Tang, M.H.Y. and Ng, E.H.Y. (2019) Knowledge, Attitude and Ethical Consideration of Chinese Couples Requesting Preimplantation Genetic Testing in Hong Kong. *Journal of Obstetrics and Gynaecology Research*, **45**, 1096-1105. <https://doi.org/10.1111/jog.13940>
 - [50] Chin, A.H.B., Al-Balas, Q., Ahmad, M.F., Alsomali, N. and Ghaly, M. (2023) Islamic Perspectives on Polygenic Testing and Selection of IVF Embryos (PGT-P) for Optimal Intelligence and Other Non-Disease-Related Socially Desirable Traits. *Journal of Bioethical Inquiry*, **21**, 441-448. <https://doi.org/10.1007/s11673-023-10293-0>
 - [51] Siermann, M., van der Schoot, V., Bunnik, E.M. and Borry, P. (2024) Ready for Polygenic Risk Scores? An Analysis of Regulation of Preimplantation Genetic Testing in European Countries. *Human Reproduction*, **39**, 1117-1130. <https://doi.org/10.1093/humrep/deae049>
 - [52] del Collado, M., Andrade, G.M., Gonçalves, N.J.N., Fortini, S., Perecin, F. and Carriero, M.M. (2023) The Embryo Non-Invasive Pre-Implantation Diagnosis Era: How Far Are We? *Animal Reproduction*, **20**, e20230069. <https://doi.org/10.1590/1984-3143-ar2023-0069>
 - [53] Fodina, V., Dudorova, A. and Erenpreiss, J. (2021) Evaluation of Embryo Aneuploidy (PGT-A) and Endometrial Receptivity (ERA) Testing in Patients with Recurrent Implantation Failure in ICSI Cycles. *Gynecological Endocrinology*, **37**, 17-20. <https://doi.org/10.1080/09513590.2021.2006466>
 - [54] Cozzolino, M., Diaz-Gimeno, P., Pellicer, A. and Garrido, N. (2020) Evaluation of the Endometrial Receptivity Assay and the Preimplantation Genetic Test for Aneuploidy in Overcoming Recurrent Implantation Failure. *Journal of Assisted Reproduction and Genetics*, **37**, 2989-2997. <https://doi.org/10.1007/s10815-020-01948-7>
 - [55] Kozyra, O., Medvediev, M. and Tinelli, A. (2024) Predictions of Live Birth in IVF Programs of Patients with Recurrent Implantation Failure. *European Journal of Obstetrics & Gynecology and Reproductive Biology*, **303**, 331-336. <https://doi.org/10.1016/j.ejogrb.2024.11.007>
 - [56] Varga, K., Tóth, N., Bogár, É.B., Csontos, L., Szabó, K., Debreceni, D., *et al.* (2019) The Demise of Preimplantation Genetic Testing for Aneuploidy (PGT-A) in Hungary and Its Effect on Patient Care. *European Journal of Medical Genetics*, **62**, Article 103669. <https://doi.org/10.1016/j.ejmg.2019.05.008>
 - [57] Ping, P., Liu, Y., Zheng, Z., Ma, Y., Dong, F. and Chen, X. (2023) Association of Embryo Aneuploidy and Sperm DNA Damage in Unexplained Recurrent Implantation Failure Patients under NGS-Based PGT-A Cycles. *Archives of Gynecology and Obstetrics*, **308**, 997-1005. <https://doi.org/10.1007/s00404-023-07098-2>
 - [58] Cimadomo, D., Taggi, M., Cimadomo, V., Innocenti, F., Albricci, L., Colamaria, S., *et al.* (2024) Value of PGT-A When Only One or Two Blastocysts Are Obtained: Propensity-Score Matching and Cost-Effectiveness Study. *Ultrasound in Obstetrics & Gynecology*, **65**, 106-113. <https://doi.org/10.1002/uog.29148>

-
- [59] Zuckerman, S., Gooldin, S., Zeevi, D.A. and Altarescu, G. (2020) The Decision-Making Process, Experience, and Perceptions of Preimplantation Genetic Testing (PGT) Users. *Journal of Assisted Reproduction and Genetics*, **37**, 1903-1912. <https://doi.org/10.1007/s10815-020-01840-4>
- [60] He, T., Shi, W., Xue, X. and Shi, J. (2025) Impact of Blastocyst Biopsy for Preimplantation Genetic Testing on Maternal and Neonatal Outcomes Following Single Frozen Embryo Transfer Cycles. *BMC Pregnancy and Childbirth*, **25**, Article No. 74. <https://doi.org/10.1186/s12884-024-07107-5>
- [61] Zhou, R., Dong, M., Huang, L., Wang, S., Wang, Z., Xu, L., *et al.* (2025) Comparison of Cumulative Live Birth Rates between Progesterin and GnRH Analogues in Preimplantation Genetic Testing Cycles. *The Journal of Clinical Endocrinology & Metabolism*, **110**, 611-623. <https://doi.org/10.1210/clinem/dgae847>
- [62] Huang, C., Jiang, W., Zhu, Y., Li, H., Lu, J., Yan, J., *et al.* (2019) Pregnancy Outcomes of Reciprocal Translocation Carriers with Two or More Unfavorable Pregnancy Histories: Before and after Preimplantation Genetic Testing. *Journal of Assisted Reproduction and Genetics*, **36**, 2325-2331. <https://doi.org/10.1007/s10815-019-01585-9>
- [63] Lin, D., Lin, N., Zhou, Y., Li, Q. and Ma, Y. (2025) Identification of a KRT9 Gene Variant and Preimplantation Genetic Diagnosis in a Chinese Family with KRT9-Palmoplantar Epidermal Differentiation Disorder. *Hereditas*, **162**, Article No. 183. <https://doi.org/10.1186/s41065-025-00552-y>
- [64] Theodorou, E., Chronopoulou, E., Ozturk, O., Brunetti, X., Serhal, P. and Ben-Nagi, J. (2024) Impact of Double Trophoctoderm Biopsy on Reproductive Outcomes Following Single Euploid Blastocyst Transfer. *European Journal of Obstetrics & Gynecology and Reproductive Biology*, **298**, 35-40. <https://doi.org/10.1016/j.ejogrb.2024.04.033>
- [65] Ginstrom Ernstad, E., Hanson, C., Wånggren, K., Thurin-Kjellberg, A., Hulthe Söderberg, C., Syk Lundberg, E., *et al.* (2023) Preimplantation Genetic Testing and Child Health: A National Register-Based Study. *Human Reproduction*, **38**, 739-750. <https://doi.org/10.1093/humrep/dead021>
- [66] Wang, N.F., Pinborg, A. and Humaidan, P. (2025) Procedural Safety and Ongoing Monitoring and Evaluation of Embryo Diagnostics. *Fertility and Sterility*, **124**, 878-892. <https://doi.org/10.1016/j.fertnstert.2025.05.139>