· 综 述 ·

女性盆底功能障碍性疾病评估研究进展

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摘要：女性盆底功能障碍性疾病（PFD）患病率达17.8%~74.07%，约30%患者伴随焦虑、抑郁等心理问题，严重影响患者生活质量。目前PFD的评估手段以盆腔器官脱垂定量分度法、二维超声等临床常用技术为基础，但存在主观性强、操作复杂及无法实时动态评估的局限性。近年来，高密度肌电图、三维超声、特异性生物标志物及人工智能等新技术通过补充动态功能数据、分子层面证据，与临床常用技术协同实现“结构-功能-分子”多维度评估PFD。本文检索中国知网、PubMed等数据库2019—2024年发表的有关PFD评估的相关文献，对临床常用技术的应用现状和价值、新技术评估的核心特征及两者的整合路径进行综述，为PFD的个体化诊疗提供循证依据。

关键词：盆底功能障碍性疾病；高密度肌电图；生物标志物；人工智能

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Assessment of pelvic floor dysfunction in female: a review

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Abstract: The prevalence of female pelvic floor dysfunction (PFD) ranges from 17.8% to 74.07%, with approximately 30% of patients experiencing comorbid anxiety, depression, or other psychological disorders, severely impairing their quality of life. Current assessment methods for PFD are primarily based on clinical techniques such as the pelvic organ prolapse quantification and two-dimensional ultrasound. But they are limited by high subjectivity, operational complexity, and the inability to provide real-time dynamic evaluation. In recent years, emerging technologies including high-density electromyography, three-dimensional ultrasound, specific biomarkers, and artificial intelligence have complemented conventional clinical methods by providing dynamic functional data and molecular-level evidence, achieving multidimensional “structure-function-molecular” assessment of PFD. The relevant literature on PFD assessment published in CNKI, PubMed, and other databases from 2019 to 2024 were retrieved. The current application status and value of commonly used clinical techniques, the core characteristics of emerging technology assessments, and the integration path between the two were reviewed, so as to provide the evidence for individualized diagnosis and treatment of PFD.

Keywords: pelvic floor dysfunction; high-density electromyography; biomarker; artificial intelligence

女性盆底功能障碍性疾病（pelvic floor dysfunction，PFD）指由于盆底支持缺陷、损伤和退化等导致盆腔器官发生移位或功能紊乱而引起的疾病，涵盖盆腔器官脱垂（pelvic organ prolapse，POP）、尿失禁（urinary incontinence，UI）和性功能障碍（sexual dysfunction，SD）等多种问题[1-2]。研究表明，全球成年女性PFD患病率为17.8%~74.07%，其中POP患病率约2.9%~20.9%，尿失禁约9.3%~44.1%[3-6]；我国部分地区女性PFD患病率达70.19%，且随年龄增长显著升高[7]。PFD不仅导致女性躯体不适，更引发焦虑（发生率30.9%）、抑郁（发生率30.3%）等心理问题，严重降低健康相关生活质量[8]。

目前PFD的评估手段以临床常用技术，如盆腔器官脱垂定量（pelvic organ prolapse quantitation，POP-Q）分度法、二维超声和标准化问卷等为基础，但存在一定局限性。标准化问卷如盆底不适调查表简表（pelvic floor distress inventory，PFDI-20）、女性性功能指数（fe-

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male sexual function index，FSFI）等，过于依赖患者自述和医生经验，存在较大主观偏差，难以准确量化症状严重程度[9]。虽然磁共振成像（magnetic resonance imaging，MRI）、超声等影像学检查能提供详细的解剖结构信息，但在实时动态评估盆底肌功能方面存在不足，难以全面反映患者实际病情，且操作复杂、费用高昂[10-11]；此外各评估工具间缺乏有效信息整合。PFD评估新技术是通过“主观症状-客观指标-分子机制”的多维度整合实现从经验判断到数据驱动的升级。高密度肌电图（high-density electromyography，HD-EMG）、三维超声等新技术通过补充量化参数、动态数据及生物标志物，与临床常用技术协同构建评估体系，是PFD精准评估的关键。本文通过检索中国知网、PubMed等数据库，对2019—2024年有关PFD评估的相关文献进行综述，从临床常用技术的应用现状和价值出发，归纳新技术评估的核心特征及两者的整合路径，为实现PFD个性化诊疗提供循证依据。

1 盆底功能基础评估

临床常用盆底功能基础评估是PFD评估的基础，通过标准化定性或半定量指标实现初步诊断与分层，但存在量化不足、动态评估缺失等问题。目前临床常用技术包括：（1）POP-Q分度法，我国通用的POP-Q分度法是通过测量宫颈、阴道前壁、后壁及顶端距处女膜缘的距离，将POP分为正常~Ⅳ度[12]，其优势为操作简便、重复性高，是基层医院初诊的首选方法，但无法评估盆底肌功能及神经损伤状态。（2）二维经会阴超声，通过静态观察膀胱颈位置、尿道角度等指标，初步筛查压力性尿失禁，但其仅能提供二维切面信息，难以全面反映盆底三维结构及动态变化[13]。（3）尿动力学检查，通过尿流率、膀胱压力测定等量化膀胱储尿或排尿功能，评估排尿障碍类型[14]，但检查为侵入性，且无法评估盆底肌协调性。（4）标准化问卷，PFDI-20量表从脱垂、尿失禁等维度量化症状严重程度，FSFI量表评估性功能障碍[9]，但问卷依赖患者主观描述，存在个体差异（如疼痛评分偏差）。临床常用技术为PFD评估提供基础框架，但需新技术补充量化参数与动态数据，以更好地实现精准评估。

2 盆底肌电生理评估

传统表面肌电图（surface electromyography，sEMG）实现盆底肌功能的初步判断，HD-EMG等新技术通过空间分辨率提升与动态监测，实现从“肌群整体”到“单肌纤维”的精准评估。临床常用技术sEMG通过体表电极记录盆底肌群整体电活动，记录肌肉静息张力、最大收缩能力和耐力等参数[15]。但sEMG受限于邻近肌肉的电信号干扰和电极定位不确定性，其空间分辨率低，仅能反映肌群整体状态，无法定位具体肌肉，难以区分肌源性与神经源性损伤。近年来，HD-EMG技术为疾病功能性评估提供新视角，通过高密度表面肌电图（high-density surface electromyographic，HD-sEMG）检测盆底肌群相关的运动单位传导速度分析的非侵入式肌纤维评估方法[16]、新型气囊式可拉伸电极阵列[17]等技术可以获取主要肌肉的肌电位和实时肌肉状态，并根据不同病理特征选择特定肌肉分析，提高准确性和客观性。PASKARANANDAVADIVEL等[18]开发了一种新型肛门直肠HD-EMG探针，可获取粪失禁患者肛门直肠区域的量化电生理指标，用于诊断和评价预后的临床效用。DIAS等[19]通过新型阴道内HD-sEMG探针定量诊断盆底肌高张力，并精确定位过度紧张的肌肉和神经支配区，分析特定肌肉神经，使医生能够获得实时肌肉状态，提高疾病诊断的准确性和客观性。HD-EMG技术通过“精准定位结合动态监测”弥补传统sEMG的局限，但设备成本较高，需与sEMG联合用于患者复杂病情的分层诊断。

3 盆底结构影像学评估

二维超声、静态MRI奠定盆底结构解剖学基础，三维超声、动态MRI通过三维重建与实时监测，实现结构与功能的量化整合。二维超声可测量尿道角（α角）、膀胱后尿道角（β角）和膀胱颈下降距离（bladder neck descent，BND），用于初筛PFD[13]。二维超声受限于成像维度，难以评估肛提肌体积等三维结构参数；而三维超声评估技术不仅可用于评估盆底肌肉的形态和功能，还可通过定量分析监测盆底功能的变化。例如，三维超声能够有效测量盆底肌肉的体积和厚度[20]，通过测量α角、β角、BND及尿道沿其长度的4个等距点（A-D）等在不同状态下的空间位移和旋转角度，从而评估盆腔器官的活动度[21-23]，这些参数与PFD严重程度密切相关。此外，三维超声结合剪切波弹性成像技术，可以进一步评估盆底肌肉的弹性和硬度，提供关于肌肉功能状态的更多信息，从而为患者制定个性化的治疗方案[24-26]。静态MRI通过高分辨率图像显示盆底器官解剖关系，但静态成像无法反映咳嗽、排便时的动态功能，而动态MRI在识别复杂脱垂（如子宫脱垂合并其他脏器脱垂等）方面具有优势[27]。研究表明，MRI的动态成像技术可以实时观察盆底功能活动，为评估PFD提供了新视角[28-29]。此外，NESHATIAN等[30]发现，MRI测得的腰大肌脂肪分数与POP严重程度呈显著正相关，可通过比较不同时

间点的MRI影像数据有效评价治疗效果和病情进展。三维超声与动态MRI将评估从“静态结构”拓展至“动态功能”，但需以二维超声、静态MRI为初筛基础，平衡精准度与成本。

4 盆底功能相关生物标志物评估

常规炎症指标反映PFD整体病理状态，特异性生物标志物通过分子层面关联实现分型诊断与预后预测，为PFD精准评估提供分子依据。临床常规炎症因子白细胞介素-6在POP患者组织及血清中显著升高，提示慢性炎症参与疾病进展[31]，但特异性低。早期生长反应基因-2、白细胞介素-10、白细胞介素-2、白细胞介素-1β、8-羟基脱氧鸟苷（8-hydroxy-2'-deoxyguanosine，8-OHdG）、8-异前列腺素等细胞因子和炎症标志物[32-34]在PFD患者的血液和组织样本中显著升高，提示以上生物标志物可能在PFD的发生发展中起重要作用。研究显示，排尿功能障碍（dysfunctional voiding，DV）患者8-OHdG、白细胞介素-1β水平与症状评分呈正相关，总抗氧化能力（total antioxidant capacity，TAC）水平与治疗预后呈负相关，表明其可作为独立预测DV疗效的生物标志物[35]；而逼尿肌过度活动患者前列腺素E2、8-OHdG、TAC水平与膀胱排空功能指标呈正相关[36]，提示生物标志物水平升高可能反映膀胱排空功能的恶化。PFD生物标志物可能与炎症、肌肉损伤及神经功能损害等病理过程相关，为常规指标提供分子层面补充，两者联合可提升诊断精准度，结合影像学检查，能够更准确地评估PFD的严重程度，并制定相应的治疗方案，从而改善PFD患者的治疗效果和生活质量。

5 盆底功能智能化评估

随着医学大数据和人工智能（artificial intelligence，AI）技术的进步，疾病预测模型研究成为医学领域的热点。预测模型可以帮助医生早期识别疾病高危人群，采取积极预防措施，降低疾病患病率。AI技术如卷积神经网络、随机森林和列线图等已被广泛应用于PFD风险预测模型构建，通过整合临床评分（如POP-Q分度法）、影像参数（如肛提肌体积、膈肌运动度等）及问卷指标（如FSFI），评估个体患病风险与进展趋势，实现从影像学数据到临床结局的关联分析，为个体化治疗方案制定提供数据支持。研究显示，基于卷积神经网络的深度学习模型可高精度预测女性SD患者核心肌群变化，模型决定系数达0.988，优于传统回归算法[37]；基于孕期与产后临床信息的列线图模型预测PFD发生风险，部分模型一致性指数达0.789~0.835，具有良好区分度与实用价值[38]。

6 小 结

PFD评估并非依赖单一技术，而是与临床常用技术协同实现“结构-功能-分子”多维度评估。POP-Q分度法、二维超声常用技术实现初步诊断与分层，HD-EMG、三维超声和特异性生物标志物新技术补充量化参数与动态功能数据。此外，PFD评估与治疗需要泌尿科、妇科、康复医学及心理健康等多学科协作，并鼓励患者积极提问与反馈，建立信任并提高治疗方案的依从性[39-40]，改善患者生活质量。目前研究存在HD-EMG信号处理无统一规范、设备成本高，动态MRI难以普及、多中心数据缺乏等局限。因此，建议建立“基础-进阶”PFD评估路径：基层医院用POP-Q分度法结合二维超声初筛，三甲医院用HD-EMG技术联合三维超声精准分型；开展大样本研究验证技术协同价值如HD-EMG肌电值与POP-Q分度法的相关性；开发低成本便携式设备如可穿戴HD-sEMG贴片，推动精准评估向社区普及。通过技术协同与规范化应用，最终实现PFD从“经验诊疗”到“精准管理”的转变，从而改善患者健康相关生命质量。

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