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复杂性阑尾炎风险评估研究进展

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摘　要

阑尾炎是常见的急腹症，根据有无并发症可分为非复杂性阑尾炎(Uncomplicated Appendicitis, UA)和复杂性阑尾炎(Complicated Appendicitis, CA)。近年来，非手术管理(Non-operative Management, NOM)在UA中的应用逐渐增多，但手术仍是CA的主要治疗方式。因此，早期准确鉴别UA与CA、进行个体化风险评估，对优化治疗方案和改善患者预后具有重要意义。本文旨在回顾近年来关于复杂性阑尾炎诊断及风险评估的研究进展，以期提升临床医生对该病的认识，并指导临床的诊疗工作。

关键词

阑尾炎，复杂性阑尾炎，风险评估，评分系统，预测模型

Research Advances in the Risk Assessment of Complicated Appendicitis

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Abstract

Appendicitis is a common acute abdominal condition, which can be classified into uncomplicated appendicitis (UA) and complicated appendicitis (CA) based on the presence or absence of complications. In recent years, non-operative management (NOM) has been increasingly used in the treatment of UA, but surgery remains the primary approach for CA. Therefore, early and accurate differentiation between UA and CA, along with individualized risk assessment, is of great significance for optimizing treatment strategies and improving patient outcomes. This article aims to review recent research progress in the diagnosis and risk assessment of complicated appendicitis, with the goal of enhancing clinicians' understanding of the disease and guiding clinical diagnosis and treatment.

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Keywords

Appendicitis, Complicated Appendicitis, Risk Assessment, Scoring System, Prediction Model

1. 引言

阑尾炎是常见的急腹症，男性和女性患阑尾炎的终生风险分别为 8.6%和 6.7%；男性阑尾切除术的终生风险为 12.0%，女性为 23.1% [1]。全球每 10 万成年人每年有 96.5~100 人患急性阑尾炎，在全球范围内对给各地区的政府医疗体系和居民带来很大的医疗和经济负担[2]。

阑尾炎一词的鼻祖 Reginald Fitz 认为：急性阑尾炎如果不在非穿孔阶段切除阑尾将不可避免地发展为穿孔。但 Livingston 的流行病学研究发现：1970~2004 年非穿孔性阑尾炎发病率总体下降，但穿孔性阑尾炎发生率却没有报告类似降幅，这表明穿孔和非穿孔的病理进展可能存在脱节[3]。穿孔与非穿孔的阑尾炎可能属于不同的病理生理学过程。

世界急诊外科协会(WSES)指南根据有无并发症(坏疽/穿孔、阑尾周围脓肿)将阑尾炎分为非复杂性阑尾炎(Uncomplicated Appendicitis, UA)和复杂性阑尾炎(Complicated Appendicitis, CA) [4]。虽然阑尾切除术仍是阑尾炎的主要治疗方法，但有分析指出阑尾阴性切除率总体估计为 13% [5]。并且可能出现感染、切口疝、肠粘连/梗阻、阑尾残株炎等术后并发症。近年来，UA 的非手术管理(Non-Operative Management, NOM)越来越受欢迎[6]-[9]，但是手术仍是 CA 的主要治疗手段[10]-[13]。这强调了区分二者的重要性。

随着阑尾炎发病率的上升，应对阑尾炎做出高效的高质量诊断和治疗，制定针对性干预措施[14]。本文拟从病因、实验室指标、影像学检查以及评估工具等方面回顾近年来对复杂性阑尾炎诊断及风险评估的研究进展。

2. 病因与风险评估

阑尾腔梗阻引发的炎症反应是阑尾炎发生发展的核心病理基础，而导致梗阻的核心因素及疾病进展风险，与粪石、阑尾肿瘤(ANs)、感染密切相关[15]。梳理这些关键病因的作用特点，可为临床结合人群特征开展精准风险评估、优化诊疗决策提供依据。

2.1. 粪石

粪石是成人阑尾炎的关键病因，术后病理确诊的阑尾炎患者中，CT 检出率近 40%，而非阑尾炎患者仅 4%左右[16]。尽管并非所有粪石都会诱发炎症[17]，但多项研究证实其与穿孔、脓肿等复杂并发症密切相关[18] [19]。它还是提示临床优先考虑内镜或手术干预的重要信号，且抗生素治疗后需重点监测相关并发症风险。需注意的是，粪石的硬度、大小等物理指标与阑尾炎严重程度无明确关联[20]。

2.2. 阑尾肿瘤

与阑尾炎相关的阑尾肿瘤(ANs)包括腺癌、粘液囊肿及类癌瘤[21]，且 CA 与 ANs 的相关性显著高于 UA [22]-[25]，其中 CA 患者腺癌发生率更高[26]。ANs 术前诊断困难，>70 岁患者漏诊率可达 11% [27]。但多个研究指出年龄与 ANs 发生率呈正相关，40 岁后发生率逐渐升高，70 岁左右达峰[28]-[31]；且年龄

≥ 50 岁、超声提示阑尾直径 ≥ 13 mm 是预测 ANs 的独立危险因素[23]。多数 ANs 经单纯阑尾切除术即可治愈，需在评估手术指征时兼顾 ANs 相关 CA 风险[32]。

2.3. 阑尾微生物与感染

阑尾腔内正常定植需氧菌与厌氧菌(如大肠杆菌、拟杆菌属)维持肠道免疫稳态[33] [34]。阑尾腔梗阻可导致细菌过度增殖并分泌毒素，损伤黏膜上皮引发急性炎症及脓肿形成[35]。有研究表明，CA 患者阑尾微生物多样性更高，群落组成与 UA 存在差异[36] [37]，这一特征进一步支持二者病理生理学过程的独立性，但微生物组对阑尾炎进展的具体调控机制仍需深入探索。

阑尾腔梗阻是 CA 发生的核心始动因素，持续存在的粪石和阑尾肿瘤导致微生物失衡是主要相关机制。粪石与 CA 并发症密切相关，年龄 ≥ 50 岁合并阑尾直径增大提示 ANs 风险升高，这些特征为临床早期识别 CA 高危人群、制定针对性干预策略提供了重要依据。

3. 实验室指标与风险评估

实验室指标是 CA 风险评估的重要支撑，从炎症程度、穿孔风险等维度为临床鉴别提供参考。但单一指标存在固有局限，多指标联合评估是更可靠的策略。

传统炎症标志物(如 CRP、WBC)虽灵敏度较高[38] [39]，可作为 CA 的基础筛查工具，但在区分 CA 与其他腹腔炎症时特异度不足，难以满足精准评估需求。这推动了对新兴血液学参数的探索，但相关研究结果异质性显著：例如中性粒细胞与淋巴细胞比率(NLR) > 8.8 时，区分 CA 的特异度可达 100%，敏感度为 76.92% [40]；而未成熟粒细胞百分比(IG%)的诊断价值存在明显争议——Ünal 等报告其诊断效能近乎完美(AUC：0.979，敏感度：94.4%，特异度：97.9%) [41]，Turkes 的研究却显示其预测价值有限(AUC 0.693) [42]。这种差异可能与研究人群、检测方法的异质性相关，因此新兴指标纳入常规应用前，仍需大规模标准化验证。

此外，高胆红素血症作为易获取的指标，对 CA 相关穿孔具有中等程度预测价值。Alfehaid 的分析指出，总胆红素 ≥15 μmol/L、直接胆红素 ≥5 μmol/L 是预测 CA 的最佳临界值，其中总胆红素升高的敏感度为 57.6%、特异度为 73.6%，直接胆红素升高的敏感度为 54.6%、特异度为 80% [43]。

综上，传统炎症标志物、新兴血液学参数及胆红素相关指标，从不同维度为 CA 风险评估提供了依据，但均存在特异度、敏感度或证据强度不足的问题。因此，多指标联合检测可互补短板，是提升 CA 评估准确性的更可靠策略。

4. 影像学检查与风险评估

超声、计算机断层扫描(CT)扫描是最常用的成像方式。二者至今仍然是诊断急性阑尾炎的首选影像学检查，并且识别复杂性阑尾炎的能力各有优劣。

4.1. 超声

超声检查诊断 CA 的效能如下：基于病理结果，其敏感度与特异度分别为 42.2%和 90.4%，阳性预测值(PPV)与阴性预测值(NPV)分别为 45.8%和 89.0%；而基于术中所见，其敏感度与特异度则分别为 37.3%和 92.7%，PPV 与 NPV 分别为 63.4%和 81.4% [44]。此外超声的某些特征(存在不可压缩性和阑尾壁血管血流增加)在区分阑尾炎穿孔与正常阑尾具有优势[45]。其检测穿孔性阑尾炎方面的表现如下：敏感度为 44.0%，特异度为 93.1%，PPV 为 74.8%，NPV 为 78.1% [46]。由此可见：超声对 CA 的特征(脓肿、穿孔)具有高度特异性，但敏感性相对较低，这可能与操作者的水平密切相关。但是简便、快速、无辐射等优势使得超声仍是儿童以及孕妇的首选检查。

4.2. CT

CT 是目前诊断阑尾炎最常用、最推荐的影像学检查，具有极高的诊断准确率。并且低剂量增强 CT 在区分 UA 与 CA 方面的诊断效能并不逊色于标准剂量 CT，从而能够降低辐射剂量。

CT 能识别多种与 CA 高度相关的影像学特征，其诊断价值已得到多项研究验证：Iamwat 对 201 例术后病理确诊阑尾炎患者的分析显示，CT 诊断 CA 的敏感度、特异度和准确度分别达 87.2%、75.7%和 81.1%，其中黏膜强化缺损和中重度阑尾周围脂肪滞留是 CA 最敏感的 CT 特征，二者均可独立预测 CA (调整后 OR 分别为 4.62、4.41) [47]；Akçiçek、Şimşek 的研究也证实，中度/重度阑尾周围脂肪滞留、阑尾壁强化缺损及脓肿、阑尾周围积气等特征，对识别 CA 具有一定价值[48] [49]。

需强调的是，CT 诊断 CA 的效能并非依赖单一“金标准”特征。且 CT 并非绝对可靠——其存在一定漏诊率，部分患者还可能出现延迟性穿孔风险[50]。因此需整合多项 CT 特征综合判断，才能更精准地评估 CA 风险，为临床诊疗决策提供可靠依据。

4.3. MRI

MRI 对阑尾炎的诊断能力与 CT 相似，有文章指出其可达 96%~100%的敏感度、81%~96%的特异度、90%的 PPV 和 98%的 NPV [51]。但是其成像慢、延时报告、检查成本等特性限制了进一步的应用。但没有辐射对儿童及孕妇阑尾炎诊断困难时至关重要。

总的来说，影像学检查是鉴别 CA 的核心基石，超声、CT 及 MRI 需结合人群与病情个体化选择。CT 诊断准确率高，能识别多项 CA 相关特征，是成人及老年患者的优选，但其效能依赖多特征综合判断，且存在一定漏诊风险；超声以无辐射、便捷的优势成为儿童及孕妇首选，对 CA 特征特异度高但敏感度受操作者水平影响；MRI 诊断效能与 CT 相当，无辐射特性可作为特殊人群的补充检查，唯成像慢、成本高限制常规应用。

5. 复杂性阑尾炎评估工具

病因、实验室指标及影像学检查为 CA 的风险评估提供了多维度依据，而整合这些核心指标的标准化评估工具，可进一步提升 CA 鉴别与风险分层的系统性和精准性。目前已构建与验证的 CA 评估工具主要分为评分系统与预测模型，可为临床诊疗决策提供参考与支撑。

5.1. 阑尾炎的诊断评分系统

Alvarado、AIR、RIPASA 是临床常用的阑尾炎诊断评分系统。其中 Alvarado 与 AIR 评分均可评估病理严重程度，仅 AIR 评分可直接区分 UA 与 CA [52]。前瞻性研究证实，AIR 评分 ＜4 分时 CA 发生可能性极低(NPV 99%)，>8 分时 CA 占比达 66%，在年龄 ＜15 岁及症状持续>47 小时的患者中效能更优[53]。RIPASA 评分与阑尾炎病理严重程度呈显著正相关，评分越高，化脓、坏疽等复杂病变风险越大[54]。当评分 ≥12 分时，化脓、坏疽及穿孔性阑尾炎占比极高。

综上，传统诊断评分系统不仅可用于阑尾炎筛查，还能对 CA 风险进行初步分层与排除，具有重要的临床预判价值。

5.2. 复杂性阑尾炎评分系统

5.2.1. Atema 评分

Atema 评分(SAS，见表 1)是早期用于区分 UA 与 CA 的阑尾炎严重程度评分系统。以≤6 分为临界值时，其内部验证敏感度为 90.2%、特异度 70.3%，阴性预测值达 94.7%，对排除 CA 具有较高参考价值[55]。同时有研究证实，低 Atema 评分患者穿孔进展速度较慢，提示该评分可辅助评估穿孔风险[50]。

Table 1. Atema score system
表 1. Atema 评分

	得分	
	临床和 CT	临床和超声
年龄 ≥ 45 岁	2	2
体温(℃)		
≤37.0	0	0
37.1~37.9	2	2
≥38.0	4	4
症状持续时间 ≥ 48 小时	2	2
白细胞计数 > 13×10^9/L	2	2
C 反应蛋白(mg/L)		
≤50	0	0
51~100	2	4
≥100	3	5
腔外游离气体	5	-
阑尾周围积液	2	2
阑尾粪石	2	2
总计	22	19

尽管早期 SAS 缺乏充分外部验证，在后续对比研究中，Atema 评分仍被证实具有较为可靠的诊断效能[56]-[58]。而其优化版本 SAS 2.0 网页计算工具经前瞻性外部验证后，可更准确地个体化评估 CA 发生概率，为临床治疗方案的选择与沟通提供了实用工具[59]。

5.2.2. 坏疽/穿孔性阑尾炎预测评分系统

Kobayashi 等通过多因素分析筛选出与坏疽/穿孔性阑尾炎(GPA)相关的六项指标，并最终确定 CRP、阑尾最大外径、阑尾粪石为独立预测因子，据此建立了简易评分系统(见表 2) [60]。该评分以 2 分为最佳临界值，敏感度 75.3%、特异度 71.2%；按 0~1、2、3 分可将患者划分为低、中、高风险组，对应的 GPA 发生概率分别为 30.9%、63.8%和 94.4%，模型整体校准度良好(AUC 0.792)。该评分指标少、易获取、高风险预判准确，具备较好的临床推广潜力；但整体诊断效能仍有提升空间，需联合更多临床及影像学特征进一步优化与验证。

Table 2. Predictive score system of GPA
表 2. GPA 预测评分系统

变量	回归系数	得分
CRP ≥ 7 (mg/dL)	1.73	1
阑尾的最大外径 ≥ 13 (mm)	1.129	1
存在阑尾粪石	1.137	1
总分		3

5.2.3. 坏疽性阑尾炎评分系统

Suzuki 等通过多因素分析筛选出 CT 值 ≥ 24 HU、阑尾直径 ≥ 12 mm、盲肠黏膜水肿、CRP ≥ 5.4 mg/dL 四项独立预测因子，并据此构建了 0~4 分的评分模型(见表 3) [61]。根据总分可将患者分为低(0 分)、中(1~2 分)、高(3~4 分)风险三级，对应的坏疽性阑尾炎发生概率分别为 0%、15%和 97%，风险分层能力突出。该评分高度依赖 CT 量化特征，对坏疽性阑尾炎具有较强的预测能力，适用于放射科医生评估 CA，但也因此限制了其在无法行 CT 检查患者中的应用。

Table 3. Score system of Gangrenous appendicitis
表 3. 坏疽性阑尾炎评分系统

变量	相对风险(RR)	得分
CT 值 ≥ 24 HU	12.47	1
阑尾直径 ≥ 12 (mm)	17.49	1
存在盲肠黏膜水肿	54.34	1
CRP ≥ 5.4 (mg/dL)	35.58	1
总分		4

5.3. 复杂性阑尾炎预测模型

前述 CA 专项评分系统虽能实现疾病风险分层，且具备操作简便、指标易获取的优势，但受限于指标整合维度与算法设计，在捕捉多指标间潜在关联、实现个体化精准风险量化上仍有提升空间。在此基础上，整合人口学特征、临床症状、实验室检查及影像学特征的 CA 预测模型被逐步构建与验证，通过规范化算法深度挖掘多维度数据的联合预测价值，成为 CA 精准风险评估的重要发展方向。

结合表 4 中 8 项 CA 预测模型研究结果横向对比可见，传统逻辑回归模型与机器学习模型在泛化能力、临床落地适配性上呈现鲜明的优劣差异，二者均为传统评分系统的有效升级，却因设计逻辑不同适配不同临床场景。泛化能力层面，逻辑回归模型中经多中心外部验证的研究(H. Y. Kim, Hui-An Lin) AUC 稳定在 0.81~0.89，虽单中心模型可实现 AUC 0.985 的超高效能，但受指标维度限制，对不典型 CA 的识别普适性有限；机器学习模型(GBM, XGBoost)凭借多维度指标整合优势，实现了更高的诊断效能与综合指标平衡性，但其仅完成单中心内部验证，缺乏不同地域、不同医疗资源层级的人群验证，泛化能力尚未得到证实。临床落地层面，逻辑回归模型以 3~6 项易获取的核心指标为基础，操作简便、结果可量化解读，既符合急诊快速诊断的需求，也适配基层医疗机构无特殊影像学检查的条件，是目前临床可直接借鉴的实用工具；而机器学习模型虽诊断效能更优，但受数据壁垒(需完整多维度临床数据)、技术壁垒(需专业算法平台与人员)、认知壁垒(黑箱特性降低临床信任度)三重限制，暂无法在常规临床场景推广应用。

Table 4. Predictive models of CA
表 4. 复杂性阑尾炎预测模型

作者	预测因子	模型	模型性能	验证
H.Y. Kim 等[62]	CT 预测因子(阑尾壁的对比增强缺陷、脓肿、中度/重度阑尾周围脂肪滞留、腔外空气)；阑尾直径 ≥ 10 mm 或 13 mm；分段中性粒细胞 ≥ 81%	逻辑回归	验证数据集中的校准斜率为 1.03，AUC 为 0.81 (95% CI: 0.77~0.85)。敏感度、特异度、PPV、NPV 和假阴性和真阴性比例分别为 93.4% (91.8~99.1)、28.1% (13.6~24.1)、40.8% (35.0~46.8)、88.9% (79.3~95.1)、2.3%和 18.3%。	外部验证

续表

Tianlei Xu 等[63]	阑尾周围脂肪滞留(PFS)；C 反应蛋白水平(CRP ≥ 38 mg/L)；中性粒细胞与淋巴细胞比值(NLR ≥ 7)	逻辑回归	PFS、CRP 和 NLR 得分依次为 10.0、4.0 和 3.0 分。诺模图风险评分大于 11 分可预测 CA。验证队列中的 AUC 为 0.890 (95% CI: 0.832~0.933)，敏感度和特异度分别为 0.868 和 0.696。	内部验证
Hui-An Lin 等[57]	阑尾周围脂肪滞留；c 反应蛋白；中性粒细胞与淋巴细胞比值；FS；腹水；阑尾粪石	逻辑回归	以≥6 分为界值，模型 1 (逆向剔除)的敏感度和特异度分别为 82.8%和 82.8%；模型 2 (逐步筛选)的敏感度和特异度分别为 81.3%和 82.3%。C 统计量分别为 0.878 和 0.879。	外部验证
Hui Feng 等[64]	腹痛持续时间(h)；腹膜炎；总胆红素(μmol/L)。	逻辑回归	AUC 为 0.985 (95% CI, 0.975~0.994)。经 Bootstrap 法内部验证后 AUC = 0.983。	内部验证
Wei Wang 等[65]	总胆红素(μmol/L)、阑尾直径(mm)和体温(℃)这三个指标对预测 CA 的影响最显著	机器学习	GBM 算法的预测效果最优，敏感度、特异度、PPV、NPV、precision、召回率、F1 和 brier 分别为 0.9167、0.9739、0.9429、0.9613、0.9429、0.9167、0.9296 和 0.0564。	内部验证
Jia-hui Cai 等[66]	体温(>37.2℃)、呕吐、阑尾结石和阑尾周围积液	逻辑回归	AUC 为 0.87 (95%置信区间(CI)，0.80~0.93)，敏感度为 88%，特异度为 74%。	内部验证
Tianyi Ma 等[67]	体温、术前 C 反应蛋白(CRP)水平、淋巴细胞百分比、阑尾粪石、阑尾周围脂肪滞留和阑尾直径	逻辑回归	内部验证中 AUC 值为 0.82。敏感度为 74.49%，特异度为 76.36%。PPV 为 0.53，NPV 为 0.89。准确率为 0.76。	内部验证
Sunmeng Chen 等[68]	CRP、疼痛到手术的时间是否超过 24 小时、腹部肌张力、心率、血小板、体温、尿素氮、嗜酸性粒细胞、平均动脉压、血糖、单核细胞、年龄、中性粒细胞、淋巴细胞和红细胞。	机器学习	XGBoost 模型预测效果最佳，AUC、准确度、敏感度、特异度、NPV 和 PPV 分别为 0.914、0.855、0.865、0.846、0.848 和 0.897。其次是 SVM 模型，AUC、准确度、敏感度、特异度、NPV 和 PPV 分别为 0.882、0.819、0.865、0.779、0.770 和 0.871。	内部验证

基于现有研究证据，推荐 CA 初步评估最优方案为“逻辑回归模型为核心，结合临床实际灵活取舍指标”：急诊及基层医疗机构可选用仅含临床 + 实验室指标的逻辑回归模型(如 Hui Feng 等构建的腹痛持续时间 + 腹膜炎 + 总胆红素模型)，快速完成 CA 风险分层；具备 CT 检查条件的医疗机构，可采用整合影像学特征的逻辑回归模型(如 Tianlei Xu 等构建的阑尾周围脂肪滞留 + CRP + NLR 诺模图模型)，进一步提升评估准确性。同时，现有预测模型仍存在多数未完成多中心前瞻性验证、部分模型效能指标失衡等问题，未来研究需聚焦高潜力模型的泛化性验证，对机器学习模型进行指标精简与算法透明化优化，对逻辑回归模型开展更大样本的外部验证，最终推动形成适配不同医疗资源层级的标准化 CA 预测体系。

6. 结论

综上所述，随着对阑尾炎病理生理认识的深入及治疗方式的优化，对复杂性阑尾炎进行精准的风险评估已成为临床决策的关键。尽管影像学检查是诊断基石，但整合多维度数据明显有着更高的区分能力。在众多评估工具中，经过外部验证的评分系统(如 Atema 评分)及预测模型展现出了良好的应用前景。鉴于临床应用不足，未来研究应着眼于：一是明确阑尾粪石、肿瘤、特定微生物群落等病因在疾病进展中的作用，为防治复杂性阑尾炎提供依据。二是对现有高潜力预测模型进行大规模、多中心的前瞻性验证，

以评估其普适性与临床效用。最终目标是构建更高质量、个体化的风险评估体系，以指导不同阑尾炎类型治疗方式的选择，优化患者预后。

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