·专题论著·



范秋灵，医学博士，主任医师、教授、博士研究生导师，现任上海市第一人民医院肾内科主任。上海浦江人才、辽宁省“兴辽英才计划”科技创新领军人才，日本顺天堂大学医学部肾脏内科客座教授。曾于日本顺天堂大学获得医学博士学位，并赴美国哈佛医学院附属布莱根和妇女医院担任访问学者。兼任中国老年医学学会肾脏病学分会常务委员、中国抗癌协会整合肿瘤肾脏病学专业委员会委员、上海市肾内科临床质量控制专家委员会委员。长期从事肾脏病临床、教学及科研工作，擅长肾脏病理学诊断及疑难肾脏疾病诊治，主要研究方向为糖尿病肾病的发病机制及肾脏病理学研究。主持国家自然科学基金项目4项、国家重点研发计划子课题、上海市浦江人才计划等多项科研课题。在国内外学术期刊发表论文70余篇，其中30余篇发表在SCIE和ESCI收录的期刊上。担任《糖尿病肾病》等专著的副主编，参编《中国肾脏病学》等多部专著。此外，还担任《中华肾脏病杂志》等学术期刊编委。曾获沈阳市科技进步奖一等奖、辽宁省科技进步奖二等奖等。

血液系统疾病患者造血干细胞移植后肾损伤的临床病理学谱：一项单中心横断面研究

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［**摘要**］ **背景与目的：**造血干细胞移植（hematopoietic stem cell transplantation，HSCT）后肾损伤病因复杂，肾脏病理学表现具有异质性，相关临床病理学资料仍较有限。本研究旨在分析HSCT后肾损伤患者的临床病理学特征和肾脏转归，重点描述肾脏血栓性微血管病（thrombotic microangiopathy，TMA）病理学表型与临床归因，并探讨不同病理学类型与临床表现及治疗选择的关系。**方法：**采用单中心横断面研究设计，连续纳入2018年1月—2026年7月于上海市第一人民医院肾内科因HSCT后肾损伤接受经皮肾穿刺活检的成年患者。回顾性收集人口学资料、基础血液病及HSCT相关资料、肾损伤临床表现、实验室指标、肾脏病理学检查、治疗及随访资料。经逐例病理学资料复核，将病例分为肾脏TMA和非TMA病变；针对肾脏TMA病例进一步结合移植背景、临床及实验室资料和潜在混杂病因进行移植相关血栓性微血管病（transplantation-associated thrombotic microangiopathy，TA-TMA）的诊断与归因评估，并参照2023年TA-TMA国际协调共识进行高危分层。本研究经上海市第一人民医院人体试验伦理审查委员会批准（批准号：2026KS640）。**结果：**共纳入16例患者，其中男性10例（62.5%），HSCT时中位年龄为42.7（33.7，48.8）岁，肾活检时中位年龄为44.0（34.5，53.1）岁，自HSCT至肾穿刺活检时间为20.8（13.3，27.2）个月。基础疾病以急性髓系白血病或相关髓系疾病为主（10例，62.5%），15例（93.8%）接受异基因HSCT。肾活检时13例（81.3%）表现为慢性肾脏病（chronic kidney disease，CKD）/肾功能不全表型，3例（18.8%）表现为显著蛋

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白尿/肾病综合征表型；全组中位血肌酐（serum creatinine，Scr）为126.8（105.2，146.1）μmol/L，中位估算肾小球滤过率（estimated glomerular filtration rate，eGFR）为54.4（46.7，72.2）mL·min^{-1}·（1.73 m^2）$^{-1}$。病理学资料复核后，确诊肾脏TMA 11例（68.8%），非TMA病变5例（31.3%），后者包括局灶节段性肾小球硬化（focal segmental glomerulosclerosis，FSGS）/足细胞病变2例、膜性肾病2例及慢性肾小管间质/血管病变1例。11例肾脏TMA患者经过临床综合评估，3例可明确归因为TA-TMA，其余8例归因未能明确。11例肾脏TMA患者中5例接受可溶性C5b-9检测，其中2例高于参考上限。2例肾脏TMA患者接受依库珠单抗治疗，2例膜性肾病患者接受利妥昔单抗治疗。肾脏TMA组自HSCT至肾穿刺活检时间较非TMA病变组短［474（388，700）d比934（839，1 652）d；差值−533 d（95% CI: −1 401 ~ −31），*P*=0.017］。14例获随访患者的中位随访时间为11.0（6.6，23.9）个月，末次中位Scr为154.2（125.7，170.1）μmol/L；9例有末次24 h尿蛋白定量记录，为0.27（0.16，1.15）g/24 h。有限随访期内未观察到终末期肾病，长期肾脏结局仍需进一步观察。**结论：**HSCT后肾损伤病理学谱系多样，以肾脏TMA病理学表型较为常见。经皮肾穿刺活检有助于明确病理学类型，并为治疗选择提供依据。相关治疗效果及长期肾脏结局仍需更大样本研究进一步验证。

［**关键词**］ 造血干细胞移植；肾损伤；肾穿刺活检；血栓性微血管病；补体

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Clinicopathological spectrum of kidney injury after hematopoietic stem cell transplantation in patients with hematologic diseases: a single-center cross-sectional study

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［**Abstract**］ **Background and purpose:** Kidney injury after hematopoietic stem cell transplantation (HSCT) has complex etiologies and heterogeneous pathological manifestations, and relevant clinicopathological data remain limited. This study aimed to analyze the clinicopathological characteristics and kidney outcomes of patients with kidney injury after HSCT, with particular emphasis on the pathological phenotype and clinical attribution of renal thrombotic microangiopathy (TMA), and to explore the relationships between pathological types, clinical manifestations, and treatment selection. **Methods:** This single-center cross-sectional study consecutively included adult patients who underwent percutaneous kidney biopsy for kidney injury after HSCT at Shanghai General Hospital between January 2018 and July 2026. Demographic characteristics, underlying hematologic diseases, HSCT-related information, clinical manifestations of kidney injury, laboratory findings, kidney pathology, treatment, and follow-up data were retrospectively collected. Following case-by-case pathological review, patients were classified into renal TMA and non-TMA lesion groups. For patients with renal TMA, the diagnosis and clinical attribution of transplantation-associated thrombotic microangiopathy (TA-TMA) were further assessed by integrating the transplantation background, clinical and laboratory findings, and potential competing etiologies. High-risk stratification was performed according to the 2023 international harmonization consensus. This study was approved by the Human Research Ethics Committee of Shanghai General Hospital (No. 2026KS640). **Results:** A total of 16 patients were included, of whom 10 (62.5%) were male. The median age at HSCT was 42.7 (33.7, 48.8) years, and the median age at kidney biopsy was 44.0 (34.5, 53.1) years. The median interval from HSCT to kidney biopsy was 20.8 (13.3, 27.2) months. Ten patients (62.5%) had acute myeloid leukemia or related myeloid diseases, and 15 (93.8%) underwent allogeneic HSCT. At kidney biopsy, 13 patients (81.3%) presented with a chronic kidney disease or kidney dysfunction phenotype, whereas 3 (18.8%) presented with marked proteinuria or a nephrotic syndrome phenotype. The median serum creatinine level was 126.8 (105.2, 146.1) μmol/L, and the median estimated glomerular filtration rate was 54.4 (46.7, 72.2) mL·min^{-1}·(1.73 m^2)$^{-1}$. After pathological review, renal TMA was diagnosed in 11 patients (68.8%), and non-TMA lesions were identified in 5 patients (31.3%), including focal segmental glomerulosclerosis/podocyte lesions in 2 patients, membranous nephropathy in 2 patients, and chronic tubulointerstitial/vascular lesions in 1 patient. Among the 11 patients with renal TMA, 3 were definitively attributed to TA-TMA, whereas TA-TMA attribution remained indeterminate in the other 8 patients. Soluble C5b-9 was measured in 5 patients with renal TMA, of whom 2 had values above the upper reference limit. Two patients with renal TMA received eculizumab, and 2 patients with membranous nephropathy received rituximab. The interval from HSCT to kidney biopsy was shorter in the renal TMA group than in the non-TMA lesion group［474 (388, 700) d *vs* 934 (839, 1 652) d; difference, -533 d (95% CI: -1 401 to -31); *P*=0.017］. Among the 14 patients with follow-up data, the median follow-up duration was 11.0 (6.6, 23.9) months, and the median serum creatinine level at the last follow-up was 154.2 (125.7, 170.1) μmol/L. Nine patients had available 24 h urinary protein measurements at the last follow-up, with a median value of 0.27 (0.16, 1.15) g/24 h. No end-stage kidney disease was observed during the limited follow-up period, and long-term kidney outcomes require further investigation. **Conclusion:** Kidney injury after HSCT encompasses diverse pathological types, among which the renal TMA phenotype is relatively common. Percutaneous kidney biopsy facilitates pathological

classification and provides evidence to guide treatment selection. The efficacy of relevant treatments and long-term kidney outcomes require further validation in larger studies.

［**Key words**］Hematopoietic stem cell transplantation; Kidney injury; Kidney biopsy; Thrombotic microangiopathy; Complement

随着造血干细胞移植（hematopoietic stem cell transplantation，HSCT）适应证的不断拓展及围移植期支持治疗的进步，受者长期生存率显著提升，远期脏器并发症日益成为制约患者生活质量及长期预后的关键因素[1-2]。肾损伤是HSCT后常见但易被低估的并发症，临床可表现为急性肾损伤、慢性肾脏病（chronic kidney disease，CKD）、蛋白尿、血尿、高血压或肾病综合征（nephrotic syndrome，NS）等多种形式[3]。肾功能受损不仅限制抗感染药物、免疫抑制剂及后续抗肿瘤药物的临床应用，还显著增加进展至终末期肾病（end-stage kidney disease，ESKD）及远期死亡的风险。

HSCT后肾损伤通常由多种因素共同参与。预处理相关化疗或放疗、钙调磷酸酶抑制剂（calcineurin inhibitor，CNI）及抗感染药物肾毒性、感染、移植物抗宿主病（graft-versus-host disease，GVHD）、补体系统异常活化及移植相关内皮损伤等均可参与发病[4-5]。由于移植受者常同时处于原发血液病维持治疗、免疫重建失衡及多药暴露状态，单纯依靠血肌酐（serum creatinine，Scr）升高、估算肾小球滤过率（estimated glomerular filtration rate，eGFR）下降或蛋白尿增加等临床指标难以直接对应单一病因。既往研究显示，HSCT后肾脏病理学谱系跨度较大，以血栓性微血管病（thrombotic microangiopathy，TMA）和膜性肾病（membranous nephropathy，MN）相对常见，局灶节段性肾小球硬化（focal segmental glomerulosclerosis，FSGS）/足细胞病变、肾小管间质损伤及血管硬化亦不少见，且临床表型与病理学类型之间缺乏绝对的对应关系[4，6-7]。

经皮肾穿刺活检是判断HSCT后肾损伤性质的重要依据。对于移植后原因不明的肾功能异常、蛋白尿或血尿，肾活检有助于识别TMA相关微血管内皮损伤、免疫复合物介导的肾小球疾病、药物毒性肾损伤及慢性肾小管间质/血管病变，从而为免疫抑制剂调整、抗感染及支持治疗优化以及补体靶向药物干预提供直接依据[4-5]。然而，受限于移植后血小板减少及出血风险，国内针对HSCT后肾损伤的肾活检队列报道仍较少，组织学TMA表型与临床移植相关血栓性微血管病（transplantation-associated TMA，TA-TMA）归因之间的界定尚待深入探讨。基于此，本研究回顾性总结本中心HSCT后发生肾损伤并接受肾穿刺活检患者的临床病理学特征，重点剖析肾脏TMA的形态学特点与TA-TMA临床归因，并探讨不同病理学类型与临床表型、治疗策略及肾脏转归的关联。

1　资料和方法

1.1　研究对象

本研究为单中心横断面研究，检索2018年1月—2026年7月上海市第一人民医院虹口院区和松江院区肾内科肾穿刺活检数据库，连续筛选既往接受造血干细胞移植且于移植后因肾脏异常接受肾穿刺活检的成年患者。纳入标准为：① 患者年龄≥18岁；② 有明确HSCT病史；③ HSCT后出现肾功能异常、蛋白尿、血尿、高血压、水肿或其他提示肾脏受累的临床表现；④ 完成经皮肾穿刺活检并获得可用于分析的肾脏病理学资料。排除标准为：① 肾穿刺活检发生于造血干细胞移植前；② 既往有肾移植史或其他实体器官移植史。本研究纳入研究期间所有符合纳入和排除标准的实际可及病例，未进行先验样本量估算。本研究为院级伦理获批项目“肾活检证实的肾脏疾病谱及临床病理学特征：单中心回顾性研究”（批准号：2026KS640）的预设探索性亚组分析，经上海市第一人民医院人体试验伦理审查委员会批准并豁免患者知情同意。本文已在国家全民健康保障信息平台—医学研究登记备案信息系统注册（备案号：MR-31-26-077992）。

1.2　临床资料收集

收集患者人口学资料、基础血液病、HSCT相关资料、移植后并发症、临床用药、肾损伤临床表现及肾活检时实验室指标。同时收集肾穿刺活检后随访资料，包括Scr、eGFR及尿蛋白等指标。实验室指标包括Scr、血尿素氮（blood urea nitrogen，BUN）、血尿酸（serum uric acid，UA）、血清白蛋白（serum albumin，ALB）、血清总蛋白（total protein，TP）、总胆固醇（total cholesterol，TC）、血红蛋白（hemoglobin，Hb）、白细胞计数（white blood cell count，WBC）、血小板计数（platelet count，PLT）、乳酸脱氢酶

（lactate dehydrogenase，LDH）、补体C3（complement component 3，C3）、补体C4（complement component 4，C4）、总补体溶血活性（50% hemolytic complement activity，CH50）及可溶性C5b-9（soluble C5b-9，sC5b-9）、24 h尿蛋白定量、尿白蛋白/肌酐比值（urinary albumin-to-creatinine ratio，UACR）及尿沉渣检查（urinary sediment examination）。采用2021年慢性肾脏病流行病学协作组（Chronic Kidney Disease Epidemiology Collaboration，CKD-EPI）肌酐公式计算eGFR[8]，eGFR分层参照2024年改善全球肾脏病预后组织（Kidney Disease：Improving Global Outcomes，KDIGO）慢性肾脏病G分期标准[9]。临床数据提取由双人独立核对原始病历、检验报告及正式病理学报告，缺失数据按实际可用例数统计，不作人工插补。

1.3 病理学资料与分组定义

所有患者均接受B超引导下经皮肾穿刺活检。肾组织常规行光镜、免疫荧光及电镜检查，观察肾小球、肾小管、肾间质及血管病变。根据肾活检时主要临床表现，将患者互斥归类为CKD/肾功能不全表型和显著蛋白尿/肾病综合征表型。后者依据24 h尿蛋白、血清白蛋白、水肿及临床诊断综合判断，不等同于所有病例均满足经典肾病综合征诊断标准。

肾脏病理学检查结果由研究团队结合正式病理学检查报告及光镜、免疫荧光和电镜结果逐例复核。根据病理学检查结果进行复核，将病例分为肾脏TMA和非TMA病变两类。肾脏TMA定义为肾组织存在符合TMA的微血管内皮损伤性病理学改变，包括肾小球内皮细胞肿胀或损伤、内皮下疏松增宽、系膜溶解、毛细血管袢腔受压或狭窄、基膜双轨样改变以及小动脉或其他微血管损伤等；具体病例可呈不同程度和组合的上述改变。非TMA病变指主要病理学诊断为其他肾小球、肾小管间质或血管病变，且经复核不足以诊断肾脏TMA。伴随或重叠病变另行记录。

病理学检查结果经过复核后明确存在肾脏TMA的患者，进一步进行TA-TMA归因评估。TA-TMA临床诊断参照2023年EBMT、ASTCT、APBMT及CIBMTR国际协调共识[10]。分别评估肾脏组织病理学证据与修订Jodele临床/实验室诊断标准，即在14 d内至少2个时间点满足7项指标中的≥4项：① 贫血；② 血小板减少；③ LDH高于正常值上限；④ 外周血出现破碎红细胞；⑤ 高血压；⑥ sC5b-9高于正常值上限；⑦ 蛋白尿，定义为随机尿蛋白/肌酐比值≥1 mg/mg。肾脏组织学TMA证据与临床/实验室诊断标准分别记录。TA-TMA高危分层依据同一共识进行判定。

1.4 治疗与随访

记录肾活检后主要治疗措施，包括血压和容量管理、感染控制、CNI调整，以及依库珠单抗、利妥昔单抗等治疗，同时记录去纤苷的用药情况及适应证。随访截至2026年8月9日，收集末次随访时的Scr、eGFR、24 h尿蛋白以及是否进展至ESKD或接受肾脏替代治疗。

1.5 统计学处理

采用Python 3.13.5（SciPy 1.17.0）软件进行统计分析。鉴于样本量较小，计量资料统一以中位数及四分位数［M（P_{25}，P_{75}）］表示，计数资料以例数和百分率［n（%）］表示。肾脏TMA组与非TMA病变组间的探索性比较中，计量资料采用双侧Mann-Whitney U检验，并计算Hodges-Lehmann位置差及其95% CI；计数资料采用双侧Fisher精确概率法，计算比值比（odds ratio，OR），其95% CI采用对数OR的Wald方法估计，列联表存在0频数时采用Haldane-Anscombe校正。所有显著性检验均为双侧检验。P<0.05为差异有统计学意义。

2 结 果

2.1 患者基线特征与HSCT相关资料

2018—2026年上海市第一人民医院肾内科共有1 648例患者接受肾穿刺活检，其中22例患者有HSCT治疗史。排除6例肾穿刺活检发生于HSCT前的患者，最终纳入16例，患者筛选流程见图1。16例患者中，男性10例（62.5%）、女性6例（37.5%）。HSCT时年龄为42.7（33.7，48.8）岁，肾穿刺活检时年龄为44.0（34.5，53.1）岁。HSCT至肾穿刺活检时间为20.8（13.3，27.2）个月。

基础血液病以髓系疾病为主，急性髓系白血病或急性髓系相关疾病10例（62.5%），急性淋巴细胞白血病3例（18.8%），骨髓增生异常综合征、重型再生障碍性贫血和慢性粒细胞白血病急髓变各1例（均为6.3%）。15例（93.8%）接受异基因HSCT，1例（6.3%）接受自体移植；全队列亲缘供者12例（75.0%）。

与移植及肾损伤相关临床背景方面，14例

（87.5%）有CNI使用或暴露记录，8例（50.0%）有明确肾外GVHD记录，6例（37.5%）存在血管内皮生长因子及其受体通路相关药物暴露，其中5例（31.3%）为全身用药，1例（6.3%）为眼内雷珠单抗注射。其余基线及移植相关资料见表1。

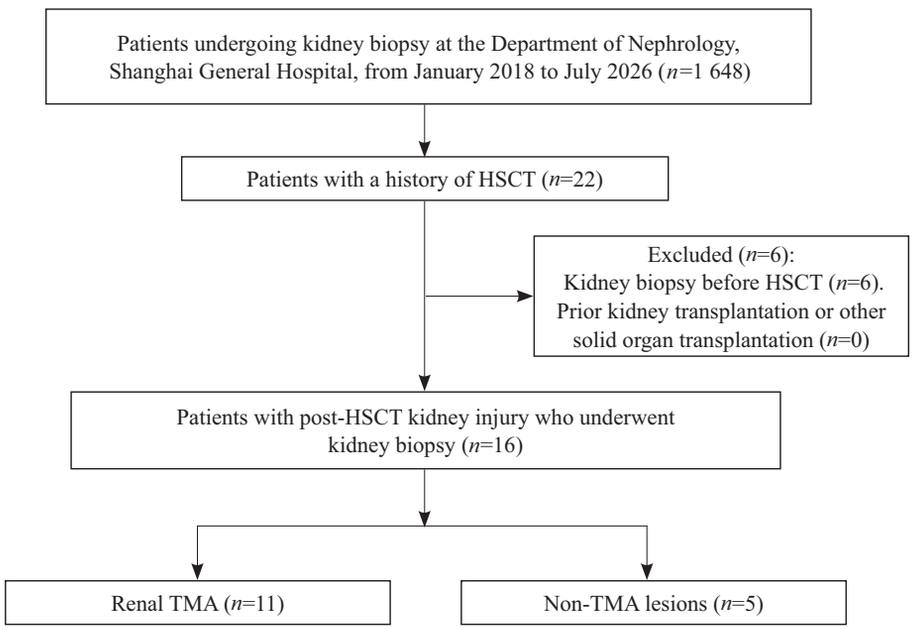


图1 HSCT后肾损伤患者筛选及肾脏病理学分组流程

Fig. 1 Flowchart of patient selection and renal pathological classification after hematopoietic stem cell transplantation

2.2 肾损伤临床表型与肾穿刺活检时实验室指标

肾穿刺活检时，16例患者中13例（81.3%）以CKD或不同程度肾功能不全为主要临床表型，3例（18.8%）表现为显著蛋白尿/肾病综合征表型。15例（93.8%）存在尿潜血阳性或尿红细胞异常，7例（43.8%）有水肿记录，7例（43.8%）有高血压，肾穿时均未接受透析。

16例患者肾穿刺活检时Scr为126.8（105.2，146.1）μmol/L，eGFR为54.4（46.7，72.2）mL·min^{-1}·（1.73 m^2）$^{-1}$。其中8例（50.0%）患者的eGFR为45～59 mL·min^{-1}·（1.73 m^2）$^{-1}$。同期24 h尿蛋白为0.61（0.26，2.96）g/24 h，血清白蛋白为38.8（35.2，39.8）g/L。血液学检查显示，Hb、PLT及LDH分别为102.5（82.8，107.5）g/L、123.5（95.0，177.2）×10^9/L和199.0（171.8，219.7）U/L。

补体相关检查方面，5例患者有sC5b-9检测结果，其中2例高于各自检测报告的参考上限。另有1例患者接受补体/TMA/C3G相关遗传学检测，未检出可解释其临床表型的致病或疑似致病变异。其余临床及实验室指标见表2。

2.3 肾脏TMA患者的临床与实验室特征

11例肾脏TMA病理学表型组患者中，男性8例（72.7%）、女性3例（27.3%），肾穿刺活检时年龄为40.5（32.3，50.0）岁。9例（81.8%）以CKD/肾功能不全为主要临床表型，2例（18.2%）表现为显著蛋白尿/肾病综合征表型。11例患者均存在血尿或尿红细胞异常，7例（63.6%）有水肿记录，6例（54.5%）有高血压。同期Scr为127.1（108.1，147.1）μmol/L，eGFR为57.3（50.0，72.5）mL·min^{-1}·（1.73 m^2）$^{-1}$，24 h尿蛋白为0.47（0.25，1.39）g/24 h。

结合肾脏病理学表现、HSCT后时间关系、移植相关临床背景及其他潜在TMA相关因素，对11例患者进一步进行TA-TMA归因评估。其中3例（患者3、13、15）具有充分的临床病理学证据，可明确归为TA-TMA；其余8例因临床证据有限或存在其他潜在相关因素，尚不能明确TA-TMA归因。3例明确TA-TMA患者中，患者3和患者15的sC5b-9均高于各自检测报告的参考上限，具有高危特征；患者13因部分高危指标缺失，无法完成风险分层。

2.4 肾脏病理学类型及临床表型对应关系

16例患者均接受肾穿刺活检并获得病理学资料。经正式病理学报告及光镜、免疫荧光和电镜结果逐例复核，11例（68.8%）可明确诊断为肾脏TMA，5例（31.3%）为非TMA病变。肾脏TMA主要表现为肾小球内皮细胞损伤、内皮下疏松增宽、系膜溶解、毛细血管袢腔受压或狭窄、节段性双轨样改变以及小动脉或其他微血管

表1 16例患者HSCT时基线及移植相关资料

Tab. 1 Baseline and transplantation-related characteristics of the 16 patients

Characteristics	Results
Age at HSCT/year	42.7 (33.7, 48.8)
Age at kidney biopsy/year	44.0 (34.5, 53.1)
Time from HSCT to kidney biopsy/month	20.8 (13.3, 27.2)
Gender *n* (%)	
Male	10 (62.5)
Female	6 (37.5)
Underlying hematologic disease *n* (%)	
Acute myeloid leukemia or related myeloid diseases	10 (62.5)
Acute lymphoblastic leukemia	3 (18.8)
Myelodysplastic syndrome	1 (6.3)
Chronic myeloid leukemia in myeloid blast crisis	1 (6.3)
Severe aplastic anemia	1 (6.3)
Transplant type *n* (%)	
Allogeneic HSCT	15 (93.8)
Autologous HSCT	1 (6.3)
Post-transplantation characteristics and exposures *n* (%)	
Documented CNI use or exposure	14 (87.5)
Documented extrarenal GVHD	8 (50.0)
Documented hemorrhagic cystitis	2 (12.5)
RASi use	7 (43.8)
Exposure to VEGF/VEGFR pathway-targeting agents	Systemic, 5 (31.3); intraocular, 1 (6.3)

Continuous variables are expressed as median (25th, 75th percentiles), and categorical variables as *n* (%). HSCT: Hematopoietic stem cell transplantation; CNI: Calcineurin inhibitor; GVHD: Graft-versus-host disease; RASi: Renin-angiotensin system inhibitor; VEGF: Vascular endothelial growth factor; VEGFR: Vascular endothelial growth factor receptor.

损伤，不同病例的病变程度及组合存在差异。5例非TMA病变包括FSGS/足细胞病变2例（12.5%）、膜性肾病2例（12.5%）和慢性肾小管间质/血管病变1例（6.3%）。

结合临床表型，肾脏TMA患者主要表现为CKD/肾功能不全；显著蛋白尿/肾病综合征表型主要见于膜性肾病或合并足细胞损伤的病例，病理学类型与临床表型对应关系见表3。部分患者存在不同肾脏病理学改变相互重叠的情况。如患者9在明确肾脏TMA的同时伴致密物沉积病，可见C3沉积及肾小球基膜致密层电子致密物沉积。患者3和15的代表性肾脏TMA病理学图像及患者14的膜性肾病病理学图像见图2。

2.5 肾脏TMA与非TMA病变的探索性比较

根据病理学分类，16例患者分为肾脏TMA组11例（68.8%）和非TMA病变组5例（31.3%）。肾脏TMA组HSCT至肾穿刺活检时间为474（388，700）d，非TMA病变组为934（839，1 652）d，Hodges-Lehmann位置差为−533 d（95% CI: −1 401 ~ −31 d，P=0.017）；前者尿酸水平较高［386.0（366.9，449.0）μmol/L比247.8（232.3，321.3）μmol/L］，位置差为138.2 μmol/L（95% CI: 24.4 ~ 240.7 μmol/L，P=0.031）。其余探索性比较见表4。

2.6 治疗及肾脏随访与转归

本组11例肾脏TMA患者中，2例接受依库珠单抗治疗。患者3经临床病理学综合评估明确

表2 16例HSCT后肾损伤患者肾穿时临床及实验室指标

Tab. 2 Clinical and laboratory characteristics at kidney biopsy in 16 patients with kidney injury after HSCT

Characteristics	Results
Clinical phenotypes and manifestations *n* (%)	
CKD/renal insufficiency	13 (81.3)
Marked proteinuria/nephrotic syndrome phenotype	3 (18.8)
Documented edema	7 (43.8)
Positive urine occult blood or abnormal urinary red blood cells	15 (93.8)
Hypertension	7 (43.8)
Dialysis at kidney biopsy	0 (0.0)
Kidney function and proteinuria parameters	
Age at kidney biopsy/year	44.0 (34.5, 53.1)
Time from HSCT to kidney biopsy/month	20.8 (13.3, 27.2)
Scr/(μmol·L^{-1})	126.8 (105.2, 146.1)
eGFR/［mL·min^{-1}·(1.73 m^2)$^{-1}$］	54.4 (46.7, 72.2)
24 h urinary protein excretion/g	0.61 (0.26, 2.96)
UACR/(mg·g^{-1})	177.11 (59.33, 474.90)
Serum albumin/(g·L^{-1})	38.8 (35.2, 39.8)
Total protein/(g·L^{-1})	61.8 (57.3, 66.5)
Total cholesterol/(mmol·L^{-1})	5.11 (4.49, 6.25)
BUN/(mmol·L^{-1})	8.51 (7.26, 11.87)
Uric acid/(μmol·L^{-1})	375.5 (291.1, 415.5)
Hematologic and complement-related parameters	
Hb/(g·L^{-1})	102.5 (82.8, 107.5)
WBC/(×10^9·L^{-1})	5.42 (4.72, 6.25)
PLT/(×10^9·L^{-1})	123.5 (95.0, 177.2)
LDH/(U·L^{-1})［122-222］	199.0 (171.8, 219.7)
C3/(g·L^{-1})［0.75-1.75］(*n*=14)	1.02 (1.00, 1.24)
C4/(g·L^{-1})［0.14-0.40］(*n*=14)	0.35 (0.27, 0.39)
CH50/(U·mL^{-1})［≥41］(*n*=15)	58.33 (45.70, 60.30)
sC5b-9/(ng·mL^{-1})［72-252］(*n*=5)	179.0 (119.8, 286.0); elevated in 2/5 (40.0%)
Complement/TMA/C3G-related genetic testing *n* (%)	1 (6.3); negative

Data are presented as median (P25, P75) or *n* (%). Values in square brackets indicate laboratory reference intervals.HSCT: Hematopoietic stem cell transplantation; CKD: Chronic kidney disease; Scr: Serum creatinine; eGFR: Estimated glomerular filtration rate, calculated using the 2021 CKD-EPI creatinine equation; UACR: Urinary albumin-to-creatinine ratio; BUN: Blood urea nitrogen; Hb: Hemoglobin; WBC: White blood cell count; PLT: Platelet count; LDH: Lactate dehydrogenase; C3: Complement component 3; C4: Complement component 4; CH50: Total hemolytic complement activity; sC5b-9: Soluble C5b-9; TMA: Thrombotic microangiopathy; C3G: C3 glomerulopathy.

归因为TA-TMA，肾穿刺活检时伴重度肾小管间质病变。依库珠单抗治疗后，其血小板计数恢复，sC5b-9由396 ng/mL降至64.71 ng/mL；肾穿后随访35.4个月，eGFR由35.1 mL·min^{-1}·（1.73 m^2）$^{-1}$变为35.7 mL·min^{-1}·（1.73 m^2）$^{-1}$，肾功能未见明显改善。患者15在肾损伤及肾穿刺活检时仍有索拉非尼暴露，主要接受支持治疗；其既往因重度肝窦阻塞综合征接受去纤苷治疗，并非针对肾脏TMA。

非TMA病变患者中，2例膜性肾病患者接受利妥昔单抗治疗。患者14肾脏病理学类型以膜性肾病为主，伴FSGS/足细胞损伤，组织PLA2R阴性、FAT1染色阳性。接受利妥昔单抗治疗后，

表3　16例HSCT后肾损伤患者病理学类型及临床表型对应关系

Tab. 3　Renal pathological categories and associated clinical phenotypes in 16 patients with kidney injury after HSCT

Predominant renal pathology	*n* (%)	Clinical presentation	Pathological findings
Renal TMA	11 (68.8)	Predominantly CKD/renal dysfunction, with proteinuria or hypertension in some patients	Microvascular endothelial injury; FSGS, dense deposit disease, or chronic tubulointerstitial/vascular lesions may coexist
FSGS/podocytopathy	2 (12.5)	Proteinuria or CKD/renal dysfunction	Predominant segmental sclerosis, podocyte injury, or foot process effacement, with chronic ischemic or vascular changes
Membranous nephropathy	2 (12.5)	Marked proteinuria or a nephrotic syndrome phenotype	One case with concomitant FSGS/podocyte injury; one with PLA2R-positive stage Ⅱ membranous nephropathy, mild acute tubular injury, and mild TMA-like changes
Chronic tubulointerstitial/vascular lesions	1 (6.3)	CKD/renal dysfunction	Predominant tubular atrophy and interstitial fibrosis, with intrarenal arterial and chronic ischemic changes

Patients were classified into mutually exclusive categories according to the predominant renal pathological findings. Data are presented as *n* (%). HSCT: Hematopoietic stem cell transplantation; TMA: Thrombotic microangiopathy; CKD: chronic kidney disease; FSGS: Focal segmental glomerulosclerosis; PLA2R: Phospholipase A2 receptor.

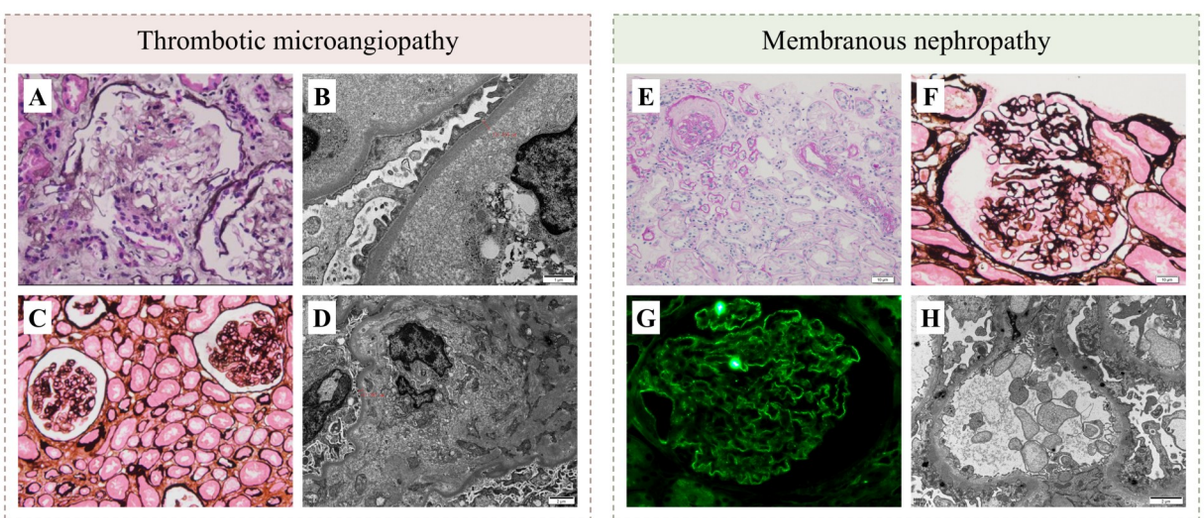


图2　造血干细胞移植后肾损伤患者的代表性肾脏病理学表现

Fig. 2　Representative renal pathological findings in patients with kidney injury after hematopoietic stem cell transplantation

A-D: Renal thrombotic microangiopathy (TMA). Panels A and B show renal pathological findings in patient 3. A: Periodic acid-silver methenamine (PASM) staining demonstrates alterations of glomerular capillary loops and focal mesangiolysis (×400). B: Transmission electron microscopy (TEM) shows widening of the subendothelial space along the glomerular capillary wall (×15 000; scale bar, 1 μm). Panels C and D show renal pathological findings in patient 15. C: PASM staining shows glomerular and surrounding tubulointerstitial structures (×200). D: TEM demonstrates subendothelial widening and associated microvascular endothelial injury (×8 000; scale bar, 2 μm). E-H: Membranous nephropathy in patient 14. E: Periodic acid-Schiff (PAS) staining shows the overall glomerular and tubulointerstitial morphology (×200). F: PASM staining demonstrates glomerular capillary loops and basement membrane morphology (×400). G: Paraffin-section immunofluorescence staining for κ light chains shows staining along the glomerular capillary walls (×400). H: TEM shows glomerular basement membrane alterations associated with subepithelial electron-dense deposits (×8 000; scale bar, 2 μm).

随访6.3个月，24 h尿蛋白由3.42 g/24 h降至0.12 g/24 h，肾功能基本稳定。患者16为PLA2R阳性Ⅱ期膜性肾病，同样接受利妥昔单抗治疗，随访1.3个月时24 h尿蛋白由13.23 g/24 h变为14.65 g/24 h，仍处于早期治疗观察阶段。

本组16例患者中，14例获得至少一次肾穿刺活检后Scr随访，中位随访时间为11.0（6.6，23.9）个月。14例患者末次Scr为154.2（125.7，170.1）μmol/L；其中9例有末次24 h尿蛋白记录，为0.27（0.16，1.15）g/24 h。多数患者末次随访时仍存在不同程度的肾功能异常和（或）蛋白尿。有限随访期间无患者接受肾脏替代治疗，未观察到ESKD，长期肾脏结局仍需进一步观察。14例有随访资料患者的个体治疗经过及肾脏转归见表5。

3　讨　　论

既往关于HSCT后肾损伤的肾活检队列研究较为有限，不同中心报道的病理学谱系存在一定差异[4, 11]。Chang等[11]及Girsberger等[4]的肾

表4 肾脏TMA病理学表型组与非TMA病变组的探索性比较

Tab. 4 Exploratory comparisons between patients with renal TMA and non-TMA lesions

Variable	Renal TMA (*n*=11)	Non-TMA lesions (*n*=5)	Effect estimate (95% CI)	*P* value
Demographic and transplantation-related characteristics				
Male *n* (%)	8 (72.7)	2 (40.0)	OR=4.00 (0.43, 37.11)	0.299
Age at HSCT/year	39.8 (30.8, 48.4)	47.2 (43.7, 48.6)	−7.4 (−20.6, 6.7)	0.308
Age at kidney biopsy/year	40.5 (32.3, 50.0)	50.9 (44.9, 52.9)	−9.9 (−22.1, 4.6)	0.257
Allogeneic HSCT *n* (%)	10 (90.9)	5 (100.0)	OR=0.64 (0.02, 18.37)	1.000
Documented extrarenal GVHD *n* (%)	5 (45.5)	3 (60.0)	OR=0.56 (0.06, 4.76)	1.000
Documented CNI exposure *n* (%)	9 (81.8)	5 (100.0)	OR=0.35 (0.01, 8.58)	1.000
Documented hemorrhagic cystitis *n* (%)	2 (18.2)	0 (0.0)	OR=2.89 (0.12, 71.94)	1.000
Time from HSCT to kidney biopsy/day	474 (388, 700)	934 (839, 1652)	−533 (−1 401, −31)	0.017
Clinical manifestations at kidney biopsy				
Documented edema *n* (%)	7 (63.6)	0 (0.0)	OR=18.33 (0.81, 416.06)	0.034
Hematuria or abnormal urinary red blood cells *n* (%)	11 (100.0)	4 (80.0)	OR=7.67 (0.26, 225.43)	0.312
Hypertension *n* (%)	6 (54.5)	1 (20.0)	OR=4.80 (0.40, 58.02)	0.308
Renal function and proteinuria				
Scr/(μmol·L^{-1})	127.1 (108.1, 147.1)	119.2 (103.0, 136.0)	7.2 (−36.1, 42.0)	0.821
eGFR/［mL·min^{-1} (1.73 m^2)$^{-1}$］	57.3 (50.0, 72.5)	47.1 (45.4, 55.8)	6.3 (−16.5, 27.9)	0.365
24 h urinary protein excretion, g/24 h	0.47 (0.25, 1.39)	3.42 (0.56, 3.69)	−2.15 (−10.43, 0.67)	0.192
UACR/(mg·g^{-1})	177.11 (51.30, 311.78)	760.96 (74.92, 5 381.14)	−461.49 (−17 022.06, 252.45)	0.396
Serum albumin/(g·L^{-1})	39.1 (38.1, 40.2)	35.3 (32.6, 38.1)	3.8 (−0.4, 14.6)	0.089
Total protein/(g·L^{-1})	62.7 (59.1, 66.7)	53.2 (51.3, 65.8)	7.68 (−18.15, 21.60)	0.308
Total cholesterol/(mmol·L^{-1})	5.03 (4.67, 6.03)	5.46 (4.55, 8.24)	−0.43 (−3.43, 1.84)	0.692
BUN/(mmol·L^{-1})	10.40 (7.89, 12.21)	7.40 (6.84, 8.02)	3.00 (−0.21, 6.91)	0.113
Uric acid/(μmol·L^{-1})	386.0 (366.9, 449.0)	247.8 (232.3, 321.3)	138.2 (24.4, 240.7)	0.031
Hematologic and complement-related parameters				
Hb/(g·L^{-1})	95.0 (78.5, 104.0)	107.0 (106.0, 109.0)	−9.0 (−33.0, 10.0)	0.174
WBC/(×10^9·L^{-1})	5.43 (4.89, 5.96)	5.03 (2.59, 6.43)	0.43 (−1.79, 2.98)	0.821
PLT/(×10^9·L^{-1})	119.0 (99.5, 144.5)	176.0 (72.0, 181.0)	−28.0 (−90.0, 69.0)	1.000
LDH/(U·L^{-1})［122-222］	200.2 (174.0, 219.7)	197.8 (165.0, 219.0)	2.7 (−145.9, 56.7)	0.910
C3/(g·L^{-1})［0.75-1.75］	1.02 (1.00, 1.35)	1.12 (1.00, 1.23)	0.02 (−0.23, 0.53)	0.887
C4/(g·L^{-1})［0.14-0.40］	0.35 (0.26, 0.39)	0.32 (0.28, 0.37)	0.005 (−0.110, 0.130)	1.000
CH50/(U·mL^{-1})［≥41］	58.33 (48.05, 61.40)	53.60 (44.95, 58.52)	3.20 (−8.00, 22.70)	0.396
sC5b-9/(ng·mL^{-1})［72-252］	179.0 (119.8, 286.0), (*n*=5); elevated in 2/5	-	-	-

Data are presented as median (P25, P75) or *n*(%). Effect estimates are expressed as Hodges-Lehmann location shifts with 95% CI for continuous variables and odds ratios (ORs) with 95% CIs for categorical variables. All comparisons are exploratory, and analyses are based on available data. UACR data were available for 9 patients in the renal TMA group and 4 in the non-TMA group; C3 and C4 data for 10 and 4 patients, respectively; and CH50 data for 11 and 4 patients, respectively. sC5b-9 data were available only for 5 patients in the renal TMA group. Values in square brackets indicate laboratory reference intervals. HSCT: Hematopoietic stem cell transplantation; TMA: Thrombotic microangiopathy; GVHD: Graft-versus-host disease; CNI: Calcineurin inhibitor; Scr: Serum creatinine; eGFR: Estimated glomerular filtration rate; UACR: Urinary albumin-to-creatinine ratio; BUN: Blood urea nitrogen; Hb: Hemoglobin; WBC: White blood cell count; PLT: Platelet count; LDH: Lactate dehydrogenase; C3: Complement component 3; C4: Complement component 4; CH50: Total hemolytic complement activity; sC5b-9: Soluble C5b-9.

表5 14例有肾穿后随访资料患者的治疗经过及肾脏转归

Tab. 5 Treatment and renal outcomes in 14 patients with kidney injury after HSCT

Patient	Predominant renal pathology	Management	Last follow-up date	Follow-up duration/month	Serum creatinine/($\mu mol \cdot L^{-1}$)	eGFR/[$mL \cdot min^{-1}$ ($1.73 m^2$)$^{-1}$]	24 h urine protein/g
Patient 2	FSGS/podocytopathy	Supportive care	Jul. 2026	7.5	136.0→145.0	40.7→37.5	0.56→Not available
Patient 3	Renal TMA	Eculizumab; supportive care	Jun. 2026	35.4	168.4→163.4	35.1→35.7	0.47→1.15
Patient 4	Chronic tubulointerstitial/vascular lesions	Mycophenolate mofetil; supportive care	Jul. 2026	21.8	163.2→171.4	45.4→42.3	3.69→0.27
Patient 5	Renal TMA	Ponatinib discontinuation following kidney injury; supportive care	Aug. 2026	18.7	127.1→180.0	57.3→37.4	0.66→Not available
Patient 7	Renal TMA	Eculizumab; supportive care	Aug. 2026	11.6	162.4→180.0	49.8→43.7	0.14→0.15
Patient 8	FSGS/podocytopathy	Glucocorticoids; supportive care	Jul. 2026	24.7	119.2→127.0	47.1→43.1	0.23→Not available
Patient 9	Renal TMA	Glucocorticoids and mycophenolate mofetil; supportive care	Mar. 2025	9.5	149.2→165.6	50.3→44.2	1.23→0.90
Patient 10	Renal TMA	Ponatinib dose reduction; supportive care	Jul. 2026	26.7	105.9→97.0	71.8→78.7	2.80→Not available
Patient 11	Renal TMA	Supportive care	Jul. 2026	10.5	131.5→166.3	53.1→39.9	0.23→0.23
Patient 12	Renal TMA	Glucocorticoids; supportive care	Jul. 2026	3.3	126.4→140.0	62.4→55.1	0.42→Not available
Patient 13	Renal TMA	Supportive care; prior rituximab for an EBV-related indication	Jul. 2026	4.1	64.1→125.2	132.6→71.9	5.24→1.30
Patient 14	Membranous nephropathy	Rituximab; supportive care	Jul. 2026	6.3	93.2→93.4	89.8→89.3	3.42→0.12
Patient 15	Renal TMA	Supportive care; prior defibrotide for VOD/SOS	Jul. 2026	24.6	145.0→191.8	45.4→32.0	0.264→0.16
Patient 16	Membranous nephropathy	Intravenous immunoglobulin and rituximab; supportive care	Aug. 2026	1.3	103.0→94.3	55.8→61.9	13.23→14.65

Follow-up duration was calculated from the date of kidney biopsy to the last follow-up assessment using the exact dates and is expressed in months. Last follow-up dates are presented as year and month. For serum creatinine, eGFR, and 24 h urine protein, values before and after the arrow represent measurements at kidney biopsy and the last follow-up assessment, respectively. The three parameters were assessed at the same follow-up visit when available. eGFR was calculated using the 2021 CKD-EPI creatinine equation. Prior treatment refers to therapy administered for indications other than the renal lesions. FSGS: Focal segmental glomerulosclerosis; TMA: Thrombotic microangiopathy; eGFR: Estimated glomerular filtration rate; CKD-EPI: Chronic Kidney Disease Epidemiology Collaboration; EBV: Epstein-Barr virus; VOD: Veno-occlusive disease; SOS: Sinusoidal obstruction syndrome. →: From kidney biopsy to the last follow-up assessment.

活检与尸检系列研究显示，HSCT后肾脏受累涵盖TMA、CNI相关肾毒性、膜性肾病、足细胞病变及小管间质损伤等多种病理学类型。黄红等[12]报道的26例HSCT后肾活检队列以及Mizuta等[13]通过对14例非亲缘脐带血移植受者的病理学检查结果进行分析后发现，在以CKD为主要临床表型的患者中，肾脏TMA及肾内微血管病变占据主导地位。与上述研究一致，本组16例患者中81.3%以CKD/肾功能不全起病，病理学类型以肾脏TMA最为常见（68.8%），其次

为FSGS/足细胞病变及膜性肾病。尽管各研究在移植供者来源、活检指征把握及病理学分类标准上有所差异，但现有证据共同表明，微血管内皮损伤与免疫介导的肾小球病变是HSCT后远期肾脏并发症的两大核心病理学基础。

肾脏TMA的病理学改变主要涉及肾小球及小血管内皮损伤。本研究11例肾脏TMA患者呈现出内皮细胞肿胀、内皮下疏松增宽、系膜溶解、基膜双轨样改变及小动脉微血管病变等不同表现，反映了肾脏微血管损伤的形态学异质性。既往研究[14-15]认为，移植预处理、GVHD、感染及CNI暴露等因素均可能参与内皮损伤的发生、发展。黄红等[12]报道的16例肾脏TMA患者中，15例曾接受CNI治疗，9例合并肾外GVHD；本研究11例中分别为9例和5例。然而，本研究非TMA组5例患者亦均有CNI暴露，提示单纯依据移植相关暴露史难以确定TMA病因。2023年国际协调共识将肾脏组织病理学证据纳入TA-TMA诊断框架[10]，但TMA形态学改变本身缺乏病因特异性。本研究严格结合移植后时间窗、修订Jodele临床/实验室标准及混杂用药史进行综合评估，发现11例经病理学检查确诊的肾脏TMA中仅3例可明确归因为TA-TMA，其余8例因临床证据不完整或存在其他潜在病因而未能明确归属，提示病理学诊断仍需结合移植相关临床背景及其他病因进行综合判断。

除肾脏TMA外，本研究还观察到膜性肾病、FSGS/足细胞病变及慢性肾小管间质/血管病变，与文献[6]报道的HSCT后肾脏病理学谱基本一致。其中，膜性肾病及合并足细胞损伤的患者多表现为显著蛋白尿或肾病综合征。值得注意的是，部分患者存在不同病理学改变重叠，如肾脏TMA合并致密物沉积病、膜性肾病伴FSGS/足细胞损伤或轻度TMA样改变，说明主导病理学分型虽有助于明确主要损伤类型，但不能完全反映同时存在的其他病变，也提示临床表型可能由多种病理学改变共同影响。FAT1是HSCT后PLA2R阴性膜性肾病的重要相关抗原[16]。本研究2例膜性肾病中，1例FAT1阳性，另1例PLA2R阳性，与文献[16-17]报道的抗原表达差异相符，提示HSCT后膜性肾病可能具有不同的抗原相关发病机制，但其具体病因仍需结合临床背景判断。

本研究探索性比较发现，肾脏TMA组自HSCT至肾穿刺活检的时间显著短于非TMA病变组（474 d *vs* 934 d，*P*=0.017）。Yap等[6]同样报道，HSCT后TMA的临床发病早于膜性肾病，这可能与微血管内皮损伤多由围移植期预处理、早期感染及高强度CNI暴露触发，而膜性肾病等免疫复合物病变常发生于免疫抑制剂减停及晚期慢性GVHD阶段有关。但肾活检时间同时受到临床表现、患者状况及活检决策等因素影响，不能据此判断病变的实际发生先后。此外，本组肾脏TMA组血尿酸水平显著高于非TMA组（386.0 μmol/L *vs* 247.8 μmol/L，*P*=0.031），与Zhang等[7]报道的TMA患者高尿酸特征相吻合。实验研究显示，高尿酸状态可通过诱发氧化应激及降低一氧化氮生物利用度，直接加剧肾脏微血管内皮功能障碍[18]。在HSCT临床背景下，血尿酸升高究竟是微血管内皮损伤的独立协同致病因素，还是受CNI肾小管排泄抑制及亚临床肾小球滤过功能减退影响的伴随表象，值得在后续研究中深入探究[19]。

HSCT后肾损伤的治疗需综合考虑病理学类型、潜在致病因素及器官损伤程度。补体活化是部分TA-TMA的重要发病机制，C5阻断治疗已成为高危患者的靶向治疗选择[20-22]。本组2例接受依库珠单抗治疗的肾脏TMA患者中，患者3在治疗后实现血小板恢复及血浆sC5b-9显著下降，但eGFR仍徘徊于基线低水平，这与其肾活检时已合并重度慢性肾小管间质纤维化可能相关。2025年国际专家共识提出，TA-TMA治疗后的血液学、补体生化指标改善与肾脏等靶器官功能恢复常存在不同步现象，临床需分维度评估疗效[23]。Jodele等[20]的大样本儿科队列也显示，64例接受依库珠单抗治疗的高危TA-TMA患儿中，长期存活者仍有超过70%存在蛋白尿，eGFR也未完全恢复至移植前水平。这提示补体相关指标或血液学表现改善后，仍需持续关注肾脏功能及蛋白尿变化。

近年来，TA-TMA靶向治疗已由C5阻断逐步拓展至其他补体通路。靶向凝集素途径相关的甘露聚糖结合凝集素相关丝氨酸蛋白酶2（mannan-binding lectin-associated serine protease-2，MASP-2）的纳索利单抗已于2025年获美国

食品药品监督管理局批准用于TA-TMA治疗[24-25]；针对替代途径因子B的伊普可泮也正在开展高危TA-TMA前瞻性多中心研究（NCT07347990）[26]。对于非TMA病变，本研究2例膜性肾病患者接受利妥昔单抗治疗，其中1例蛋白尿明显下降，另1例随访时间较短，尚不能判断其长期疗效。此外，1例患者既往因重度SOS接受去纤苷治疗，并非针对肾脏TMA。全组中位随访11.0个月，有限随访期间未观察到ESKD，但多数患者仍存在不同程度的肾功能异常和（或）蛋白尿，长期肾脏转归仍需进一步观察。

本研究存在以下局限性：① 本研究为单中心、小样本研究，仅纳入16例患者，其中肾脏TMA组11例、非TMA病变组5例。受样本量及组间例数不均衡限制，未进行多因素调整，原发血液病、移植相关并发症、药物暴露及肾功能状态等可能产生混杂。因此，HSCT至肾活检时间及血尿酸水平的组间差异仅作探索性解释，尚不能认定其与病理学类型存在独立关联。② 本研究仅纳入因肾脏异常接受肾穿刺活检的HSCT后患者，活检指征、患者全身状况和操作风险可能影响病例选择。尽管连续纳入符合条件的病例，仍无法消除肾活检相关选择偏倚，所观察到的病理学类型构成不能代表全部HSCT受者，更不能据此推算相关病变的发生率。③ 本研究回顾性收集临床资料，部分患者缺乏连续、完整的TA-TMA相关检查记录，且可能存在感染、药物暴露等竞争性病因。虽然经病理学复核明确11例肾脏TMA，但其中仅3例可明确归因于TA-TMA，其余病例的病因归属仍受资料完整性限制。④ 随访时间及检测项目不统一，14例有肾活检后Scr随访，9例有末次尿蛋白记录，可能影响肾脏转归评估；有限随访期内未见ESKD，尚不足以推断长期预后。依库珠单抗及利妥昔单抗治疗病例数少，且缺乏可比对照，不能据此评价疗效。

综上所述，HSCT后肾损伤的病理学类型多样，以肾脏TMA较为常见，同时可见膜性肾病、足细胞病变及不同病理学改变相互重叠。肾脏TMA的病理学诊断与TA-TMA的病因归属仍需加以区分。对于HSCT后出现原因不明的肾功能异常或蛋白尿的患者，在充分评估肾活检风险的基础上，肾穿刺活检有助于明确主要及伴随病理学改变，为病因判断和治疗选择提供依据。

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