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脑卒中防治的现状、挑战与未来方向

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摘要 脑卒中是我国成人死亡和残疾的首要病因, 给社会经济带来沉重负担, 是“健康中国2030”的重点防控疾病. 十余年来, 我国卒中救治水平显著提升, 溶栓、取栓等再灌注治疗普及, 急救与卒中中心体系不断完善, 治疗时间窗延长、血管再通率提高. 但仍存在突出问题, 再通获益未有效转化为神经功能改善, 部分患者预后不佳; 青年卒中发病率持续上升, 对社会劳动力构成挑战; 同时防控体系存在预防脱节、危险因素管理不足、基层能力薄弱等短板. 本文围绕急性缺血性卒中再灌注治疗瓶颈、青年卒中防控、中国特色卒中预防体系构建三方面, 综述我国脑卒中防治现状、挑战与发展方向, 为提升整体防控水平提供参考.

关键词 脑卒中、再灌注治疗、青年卒中、脑卒中防治体系

脑卒中是一类由血管闭塞或破裂引起的急性神经功能障碍疾病, 其中由血管闭塞导致的急性缺血性卒中占我国新发卒中的69.6%~72.8%, 是脑卒中的主要类型[1,2]. 目前, 脑卒中已成为我国成人死亡和残疾的首要病因, 是威胁居民健康的重要疾病之一, 给社会经济带来沉重负担. 最新流行病学数据显示, 我国脑卒中患者总数已超过2600万, 每年新发病例约400万例[1,3]. 因此, 提升脑卒中防控水平, 是实现“健康中国2030”策略目标的关键环节.

过去十余年间, 中国卒中防治事业取得了跨越式进步. 尤其是在急性缺血性卒中的救治和管理领域, 随着溶栓与取栓技术的普及、急救绿色通道的建立、卒中中心体系的完善, 急性期救治的可及性显著提高. 尤其是近几年, 缺血性卒中再灌注治疗的时间窗进一步延长, 血管再通率也有了较大的提升[4]. 然而, “时间窗延长”与“再通率提升”并未完全转化为患者神经功能恢复的提高, 仍有相当比例患者在血管再通后出现神经功能残疾甚至死亡[4~6]. 与此同时, 我国青年卒中发病率持续上升, 疾病谱呈现年轻化趋势. 这一人群具有独特的病因学特征与社会影响, 对劳动力和社会生产力构成长期挑战[7]. 此外, 我国卒中防控体系虽已初步形成, 急性期救治体系基本完善, 但仍存在预防环节脱节、危险因素管理不足、基层防控能力薄弱等问题, 这些均是影响我国卒中防控水平进一步提升的重要因素.

本文将围绕我国脑卒中防控的关键环节, 从急性缺血性卒中再灌注治疗的现状与瓶颈, 青年卒中的流行特征与防控策略, 以及构建中国特色卒中预防体系

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三个维度, 论述我国脑卒中防治的现状、面临挑战, 以及未来发展方向.

1 急性缺血性卒中再灌注治疗的现状与瓶颈

1.1 静脉溶栓治疗的进展与困境

自20世纪90年代, 阿替普酶(Alteplase, rt-PA)溶栓被证实可改善缺血性卒中患者预后以来, 静脉溶栓便成为急性缺血性卒中的标准治疗方式[8]. 传统指南推荐的治疗时间窗为发病4.5小时内, 但近年来, 随着影像学评估技术和个体化筛选方法的发展, 多项临床试验证实, 对于影像学筛选中存在“缺血半暗带”的患者, 即使在发病4.5~24小时内启动溶栓仍可从中获益[9~11].

1.1.1 静脉溶栓时间窗拓宽

WAKE-UP研究基于MRI的DWI-FLAIR不匹配结果, 验证了静脉注射rt-PA在发病时间不明的急性缺血性卒中患者中可显著改善功能预后[12]. EXTEND研究进一步显示, 在发病4.5~9小时且影像学存在缺血半暗带的患者中, rt-PA治疗可明显提高90天功能独立率[13]. HOPE研究则提示, 对于经CT灌注筛选的发病4.5~24小时患者, rt-PA同样能够改善功能结局, 虽略增症状性颅内出血风险, 但未增加病死率[14]. TRACE-Ⅲ研究首次证实, 对于发病4.5~24小时且存在缺血半暗带的前循环大血管闭塞患者, 替奈普酶(Tenecteplase, TNK)溶栓治疗安全有效[15]. 此外, EXPECTS研究针对后循环卒中发现, 即便不使用灌注成像指导, 发病4.5~24小时内给予rt-PA治疗, 也可显著提高患者第90天功能独立比例, 且不增加颅内出血和死亡风险[16]. 上述研究发现, 标志着急性缺血性卒中治疗理念已由“时间窗”向“组织窗”转变, 显著扩大了可从静脉溶栓中获益的患者人群.

1.1.2 静脉溶栓药物多样

静脉溶栓药物也取得了长足进展. 溶栓药历经了从链激酶、尿激酶到rt-PA, 再到新型第三代TNK的演进. rt-PA是目前临床应用广泛的静脉溶栓药物, 与之相比, TNK具有给药简便、血管再通率高等优点, 目前在临床中的应用日益广泛[17~19]. 近年来, 尿激酶原、瑞替普酶在卒中溶栓领域的应用, 也为临床治疗提供了更多药物选择. 然而, 值得注意的是, 目前虽然可选择的溶栓药物越来越多, 但药物的价格相对较高, 这也在一定程度上限制了静脉溶栓治疗在基层医院, 尤其是欠发达地区的普及和应用. 相较之下, 尿激酶价格低廉、可及性强, 适合我国广阔的基层医疗体系, 且我国缺血性卒中的指南和共识均推荐其作为溶栓药物[20,21]. 然而, 目前仍缺乏针对尿激酶溶栓的剂量探索, 也缺少与rt-PA或TNK头对头的对比研究, 缺乏国际公认的高质量循证医学证据, 这成为尿激酶临床应用的重要限制因素. 由中华人民共和国国家卫生健康委员会“百万减残工程”专家委员会支持的脑卒中防治科技应对重点项目——《急性缺血性卒中尿激酶静脉溶栓治疗方案优化研究》, 有望为尿激酶溶栓治疗方案提供系统性高质量的循证医学证据.

1.1.3 静脉溶栓后抗栓治疗困境

尽管近三十年来卒中救治取得了跨越式进展, 但静脉溶栓后抗栓治疗策略长期停滞不前. 自NINDS研究确立“溶栓后24小时内禁用抗栓药物”的原则后[22], 这一经验性安全策略虽有效降低脑出血风险, 却缺乏证据支撑, 同时也导致血管再闭塞与早期神经功能恶化等问题. 约10%~15%的患者与溶栓所致的血小板活化及血栓再形成[23,24], 而“溶栓后24小时内禁用抗栓药物”的限制则使部分高危患者错失最佳干预时机. 溶栓后的抗栓治疗不应“一刀切”, 而应基于患者个体风险特征与再灌注状态进行决策. 近期, 我国研究者在*The New England Journal of Medicine*和*European Heart Journal*发表的研究成果表明[25,26], 在特定患者群体中, 早期抗血小板治疗不仅安全可行, 还有望成为进一步改善患者预后的关键措施. 这一发现标志着溶栓治疗后早期抗栓策略的探索迈入新阶段.

1.2 机械取栓的突破与挑战

2015年以来, 多项关键随机对照试验确立了机械取栓在大血管闭塞卒中治疗中的核心地位[27~29]. 该技术使血管再通率提高至80%~90%, 并将患者的良好预后从不足30%提高至约50%[30~32], 成为改善卒中预后的里程碑式进展. DAWN[33]和DEFUSE-3[34]研究又将机械取栓治疗时间窗由6~12小时拓宽至24小时, BAOCHE[35]和ATTENTION研究[36]则将获益人群由前循环卒中患者拓宽至后循环卒中患者. 这些突破性成

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果为大血管闭塞所致的重症卒中患者提供了有效治疗措施.

1.2.1 机械取栓后的“无效再通”

然而, 机械取栓的临床疗效远远没有满足临床医生的期待. 虽然机械取栓治疗显著提高了血管再通率, 但仍有40%~50%的患者未获得良好的神经功能恢复, 病死率高达20%以上, 这一现象被形象地称为“无效再通”[37]. 其发生机制复杂, 既与再通前已经形成了较大体积的梗死核心有关, 也涉及再通过程中远端微栓塞、再通后的再灌注损伤及围手术期并发症等多重因素[38~40]. 因此, 单纯“开通血管”并不等同于“神经功能恢复”. 脑保护是领域内公认的最有前景的治疗措施, 目前已有上百种脑保护方法进入临床应用阶段, 但如何将其与机械取栓治疗联合进而改善患者预后, 是一个关键课题. 针对这一难题, 有研究者提出了“多阶段联合脑保护”新策略[41]. 该策略强调卒中救治应贯穿“再通前-再通中-再通后”全过程: 再通前, 通过神经保护干预延缓梗死核心扩展; 再通过程中, 优化灌注策略、减少手术相关损伤; 再通后, 抑制再灌注损伤、促进神经修复[42,43]. 通过多阶段、协同作用的干预治疗, 有望实现从“血管再通”向“良好预后”的转化.

1.2.2 血管再通后的“脑组织低灌注”

对于大血管闭塞所致的急性缺血性卒中, 尽管血管再通率已显著提高, 但仍有30%~40%患者在影像学上实现血管再通后, 脑组织水平却未获得有效脑血流灌注[44,45], 即所谓“无复流”或“不完全灌注”现象, 这是导致患者预后不良的重要原因之一. 脑组织再灌注障碍的发生机制十分复杂, 涉及微循环结构与功能的多层次损伤, 包括微血管痉挛、内皮细胞肿胀、毛细血管栓塞、血脑屏障破坏、炎症反应与再灌注损伤等多种环节的相互作用[46~48]. 这些病理改变可导致大血管再通后, 血流无法有效灌注至缺血核心及其周围的脑组织[49,50].

目前, 临床对脑组织再灌注障碍的识别和评估仍存在挑战. 尽管脑灌注成像技术可在一定程度上反映微循环灌注状态, 但缺乏统一、标准化的量化指标和诊断标准[51]. 此外, 由于其病理生理基础尚未完全阐明, 不同患者之间也存在较大差异. 与此同时, 针对这一问题的有效干预策略仍然有限. 未来研究亟需在多层次上深入研究, 包括: 建立可重复、可量化的脑组织再灌注评估体系, 整合多模态影像、电生理监测及生物标志物检测等手段, 实现从“血管再通”到“组织再灌注”的精准表征; 深入解析微循环障碍的细胞与分子机制, 为研发新型干预靶点提供理论基础; 通过高质量临床试验, 验证改善微循环灌注的治疗策略能否真正转化为患者的功能获益. 只有在“血管再通”与“组织再灌注”双重层面实现突破, 才能进一步提高急性缺血性卒中再灌注治疗的临床获益.

2 我国青年卒中防控现状与挑战

脑卒中传统上被认为是老年性疾病, 但近年来国内外研究均表明, 青年卒中的发病率呈显著上升趋势. 青年人群是社会和经济发展的核心力量, 一旦罹患卒中, 将对社会生产力和家庭造成重大负担. 目前普遍将青年卒中定义为发病年龄在18~45岁之间的卒中, 其占全部卒中的10%~14%. 全球范围内, 青年缺血性卒中约占所有缺血性卒中的10%~15%, 部分研究将“青年”范围扩展至15~49岁或18~50岁, 结论基本一致[52,53]. 基于全球疾病负担研究(Global Burden of Disease, GBD)数据分析[54], 1990~2021年间, 70岁以下人群脑卒中的年龄标准化发病率持续上升, 其中青年人群的增幅最为显著. 在我国, 青年缺血性卒中的发病率已由20世纪90年代的5%~8%上升至目前的11%~14%, 且男性发病率明显高于女性[7,55,56]. 青年卒中患者虽然起病年龄早、功能恢复潜力大, 但其复发风险较高. 有效的二级预防是改善患者预后、降低复发率、提高生活质量的关键, 因此构建系统化的青年卒中防控体系势在必行.

2.1 青年卒中的病因与危险因素特征

青年卒中的病因复杂多样, 兼具传统与特殊机制. 一项纳入1017例青年缺血性卒中患者的研究显示, 大动脉粥样硬化是最常见的病因(36.9%), 其次为其他明确病因(19.1%)和病因不明(18.1%). 除传统的动脉粥样硬化外, 青年患者中特殊病因的占比较高, 包括心源性栓塞、动脉夹层、感染性心内膜炎、血液系统疾病及药物滥用等[57,58]. 其中, 女性患者心源性栓塞比例显著高于男性, 这可能与女性口服避孕药、妊娠及产褥期等特有生理状态相关; 偏头痛性卒中和血管炎亦更常

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见于女性，而男性则以小动脉闭塞性卒中为主[59~61]. 30%~50%的青年缺血性卒中属于隐源性卒中，其中部分与卵圆孔未闭(patent foramen ovale, PFO)或静脉血栓栓塞途径有关[62~64].

近年来，我国青年卒中患者的危险因素谱发生明显变化. 传统动脉粥样硬化危险因素(如高血压、糖尿病和高脂血症等)仍占主导，但生活方式相关因素的影响不断增强. 肥胖、久坐、精神压力大、睡眠不足、吸烟及饮酒等行为在青年人群中普遍存在，代谢综合征和血压异常的发生率明显上升[7,57,65]. 此外，部分青年卒中与遗传代谢异常有关，如线粒体脑肌病伴乳酸中毒和卒中样发作综合征、家族性高同型半胱氨酸血症、抗磷脂综合征等[66,67]. 这些特征提示青年卒中不仅病因多元、机制复杂，而且危险因素管理需兼顾传统与新兴影响因素.

2.2 青年卒中防控的难点

青年卒中防控面临多重挑战，主要体现在认知、筛查和管理三方面的不足. 在认知层面，青年人群对卒中风险的认识普遍不足，仅有12%~15%的18~45岁人群了解青年卒中的危险因素. 我国40岁以下青年高血压患者的知晓率普遍低于30%，部分研究显示仅为21.6%~31.9%, 远低于中老年人群. 糖尿病在青年和中年人群中的知晓率同样不足30%, 且呈下降趋势; 血脂异常的全国知晓率约为31%，在青年群体中更低[68~70]. 此外, 高血压患者中合并血脂异常的比例较高, 但患者主动检测和管理血脂的意识明显不足.

在筛查层面，基层医疗机构对青年卒中的警惕性不足, 病因学检查往往不全面, 仅有不足40%的青年患者接受心源性栓塞相关检查(如经食管超声)，遗传代谢性疾病筛查率更低[71,72]. 在病因检出率方面，发达国家可达70%~80%，发展中国家仅为40%~65%，我国青年卒中病因检出率约为65%[73~75]，与发达国家仍存在差距.

在管理层面，青年卒中患者出院后二级预防药物依从性较差，抗血小板药物和降压药在3个月时的依从性分别仅为66.35%和69.84%，显著低于老年患者[76,77]，导致复发风险上升. 康复服务同样存在短板，目前多数康复机构侧重老年患者的生活自理能力训练，而对青年患者的职业康复及社会功能重建关注不足[78]. 心理干预的缺失亦十分突出，中国多中心研究显示，青年卒中患者抑郁发生率高达31%~50%，高于国际平均水平，但接受规范心理治疗的比例不足10%[79~81].

2.3 我国青年卒中防控体系建设

总体来看，我国青年卒中防控工作仍处于起步阶段. 现有的卒中防控体系主要聚焦于中老年人群，尚缺乏针对青年人群的健康教育、风险评估和早期筛查路径. 尽管青年与中老年卒中的防治措施在很大程度上存在共性，但由于两类人群在社会角色、心理状态、生活方式及疾病认知方面存在显著差异，青年卒中的防控亟需制定更具针对性和差异化的策略[82,83]. 借鉴国际经验，我国青年卒中防控体系的构建应从健康教育、筛查干预、科研支撑和政策保障等多个维度协同推进.

在健康教育方面，应在高校、企事业单位及社区等青年人群集中场所积极开展“青年卒中防控行动计划”, 通过多渠道宣传卒中早期症状识别与危险因素防控知识, 提升公众对青年卒中风险的认知与警觉性. 针对高危青年群体，应建立符合其特征的卒中风险评估模型，定期开展血压、血脂、血糖、体重、睡眠和心理健康等多维度的筛查与干预，促进健康生活方式的形成和维持. 在科学研究层面，有必要建立全国性青年卒中登记体系和流行病学调查平台，加强遗传学、免疫学及代谢通路等多学科协作研究，深入揭示青年卒中的病因机制，为精准防控提供坚实的科学依据. 同时，应通过政策支持与社会动员，设立青年卒中特殊防控计划，完善多部门协作机制，整合教育、卫生、医保及社区资源，形成覆盖预防、筛查、治疗与康复的全链条防控体系[83,84].

3 构建中国特色的脑卒中预防体系

近年来, 我国脑卒中防控体系取得显著进展, 尤其在急性期救治方面成效突出. 通过建设卒中急救地图、完善卒中中心和绿色通道、开展公众识别行动等举措，全国卒中救治体系实现了体系化、规范化与高效化，急性期血管再通率和救治效率显著提升[85~87]. 然而，与急救体系的快速发展相比，脑卒中预防工作仍存在薄弱环节. 一级预防与二级预防衔接不畅，从高危人群到卒中患者的长期随访管理体系尚未健全；危

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险因素的知晓率、治疗率与控制率普遍偏低, 基层防控能力亟待加强, 这些问题制约了我国从“救治型”向“预防-救治-康复一体化”防控模式的转变[88].

3.1 完善高危人群筛查与危险因素管理体系

在国家卫生健康委员会的指导下, 我国自2012年起实施的《脑卒中高危人群筛查和干预项目》, 推动建立了“预防、筛查、干预、康复”的全程管理服务模式[3,89]. 截至2023年底, 该项目累计完成1300余万人次的筛查与干预, 为脑卒中预防提供了坚实的数据基础. 然而, 《中国脑卒中防治报告(2024)》监测数据显示, 在高危人群中, 高血压的知晓率、治疗率和控制率仅为61.76%, 51.75%和28.89%; 糖尿病的知晓率、治疗率和控制率为71.06%, 49.78%, 40.33%; 血脂异常的知晓率、治疗率和控制率更低, 仅为35.22%, 10.28%, 20.12%[90]. 这些数据表明, 我国脑卒中高危人群的防控水平与国际先进水平仍有明显差距, 尤其在青中年群体中, 危险因素管理意识不足、干预不规范的问题普遍存在.

国际经验显示, 通过系统的危险因素管理和健康生活方式干预, 可显著降低卒中发病率[91,92]. 这提示我国未来脑卒中预防体系建设的重点, 应放在建立覆盖全生命周期的危险因素管理框架上, 实现从高危筛查、早期干预到二级预防的无缝衔接. 应通过标准化的筛查、转诊与干预流程, 确保高危人群得到早期识别与有效管理; 同时在卒中发作后, 强化康复治疗与再发防控, 实现从预防、急救到康复的全程管理, 逐步形成城乡覆盖、层级协同、可持续运行的脑卒中防控体系, 推动脑健康管理向精细化和精准化方向发展.

3.2 脑卒中防复发体系建设

我国脑卒中复发风险总体较高, 且具有显著的病因学特征. 东亚人群中颅内动脉粥样硬化导致的缺血性卒中比例明显高于欧美国家, 相关研究显示, 我国缺血性卒中患者中颅内动脉粥样硬化检出率为43%~47%, 而欧美人群仅约12%~20%[93~95]. 因此, 我国患者卒中一年复发率普遍高于西方国家(约6%~10% vs. 3%~5%), 且复发性卒中病情更重、致残率与死亡率更高, 带来更大的社会与经济负担[82,96,97].

为补齐卒中后长期防控的短板, 国家卫生健康委员会“百万减残工程”专家委员会提出建设“卒中防复发单元(secondary stroke prevention unit, SSPU)”[88]. 该体系以“多学科评估、个体化干预、全程随访”为核心理念, 依托卒中中心, 整合多学科及基层医疗资源, 为患者制定个体化“减残处方”, 内容涵盖危险因素控制、药物与非药物干预、生活方式调整、康复训练及心理支持等方面[98]. 通过住院-门诊-社区三级联动, 实现患者风险分层、动态评估与连续管理, 构建从卒中预防、急性救治到预防复发的闭环体系. “卒中防复发单元”的建设标志着我国脑卒中防控体系从“救治导向”迈向“预防与救治并重”的新阶段, 有望降低脑卒中年复发率, 实现脑卒中患者全生命周期健康管理目标[89,99].

4 小结与展望

过去十余年, 在政策引导与技术创新的共同推动下, 我国脑卒中防控工作取得显著进展, 尤其在急性缺血性卒中的再灌注治疗领域, 实现了多项改变临床实践的重要突破. 然而, 再灌注治疗后神经功能恢复的瓶颈、青年卒中疾病负担的上升趋势, 以及卒中防控体系的区域不平衡, 仍是当前脑卒中防治面临的主要挑战.

未来, 我国脑卒中防控应在科学研究层面深入阐明脑组织再灌注障碍与神经功能恢复的机制联系, 构建基于多模态影像、生物标志物及脑保护策略的精准个体化治疗体系, 实现从“血管再通”到“组织再灌注”, 再到最终的“神经功能重建”的跨越. 在人群防控层面, 应完善覆盖全生命周期的卒中管理链条, 将高危筛查、急性救治、二级预防与康复有机衔接; 同时建立融合健康教育、风险评估、心理支持与职业康复的青年卒中防治模式.

我国脑卒中防控正处于由“数量扩张”向“质量提升”的关键转型期. 未来十年, 将是推动脑卒中防治体系现代化、实现全民脑健康策略目标的关键窗口期.

参考文献

1 Ma Q, Li R, Wang L, et al. Temporal trend and attributable risk factors of stroke burden in China, 1990–2019: an analysis for the Global Burden

https://www.sciengine.com/doi/10.1360/SSV-2025-0374

of Disease Study 2019. Lancet Public Health, 2021, 6: e897–e906
2 Wang W, Jiang B, Sun H, et al. Prevalence, incidence, and mortality of stroke in China: results from a nationwide population-based survey of 480687 adults. Circulation, 2017, 135: 759–771
3 Tu W J, Hua Y, Yan F, et al. Prevalence of stroke in China, 2013–2019: a population-based study. Lancet Reg Health-West Pac, 2022, 28: 100550
4 Xiong Y, Li S, Wang C, et al. Chinese stroke association guidelines on reperfusion therapy for acute ischaemic stroke 2024. Stroke Vasc Neurol, 2025, 10: 527–541
5 Sharma R, Lee K. Advances in treatments for acute ischemic stroke. BMJ, 2025, 389: e076161
6 Lauer D, Sulzenko J, Malikova H, et al. Advances in endovascular thrombectomy for the treatment of acute ischemic stroke. Expert Rev Neurother, 2025, 25: 675–687
7 Gao Y, Liu K, Fang S. Analysis and projections of disease burden for different risk factors and sexes of ischemic stroke in young adults in China. Sci Rep, 2024, 14: 13339
8 Toyoda K. Intravenous rt-PA therapy for acute ischemic stroke: efficacy and limitations. Rinsho Shinkeigaku, 2009, 49: 801–803
9 Zhou Y, He Y, Campbell B C V, et al. Alteplase for acute ischemic stroke at 4.5 to 24 hours. JAMA, 2025, 334: 788
10 Günkan A, Ferreira M Y, Vilardo M, et al. Thrombolysis for ischemic stroke beyond the 4.5-hour window: a meta-analysis of randomized clinical trials. Stroke, 2025, 56: 580–590
11 Ahmad M, Ranasinghe C A, Abu-Sa'da M O, et al. Efficacy and safety of intravenous thrombolysis beyond 4.5 hours in ischemic stroke: a systematic review and meta-analysis. Diagnostics, 2025, 15: 1812
12 Thomalla G, Simonsen C Z, Boutitie F, et al. MRI-guided thrombolysis for stroke with unknown time of onset. N Engl J Med, 2018, 379: 611–622
13 Ma H, Campbell B C V, Parsons M W, et al. Thrombolysis guided by perfusion imaging up to 9 hours after onset of stroke. N Engl J Med, 2019, 380: 1795–1803
14 Luo Z, Zhou Y, He Y, et al. Treatment with intravenous alteplase in ischaemic stroke patients with onset time between 4.5 and 24 hours (HOPE): protocol for a randomised, controlled, multicentre study. Stroke Vasc Neurol, 2024, 9: 318–323
15 Xiong Y, Campbell B C V, Schwamm L H, et al. Tenecteplase for ischemic stroke at 4.5 to 24 hours without thrombectomy. N Engl J Med, 2024, 391: 203–212
16 Yan S, Zhou Y, Lansberg M G, et al. Alteplase for posterior circulation ischemic stroke at 4.5 to 24 hours. N Engl J Med, 2025, 392: 1288–1296
17 Hotz J F, Kaindl L, Krebs S, et al. Novel thrombolytic agents for acute ischemic stroke: a comprehensive review of current evidence. J Neurol Sci, 2025, 476: 123653
18 Wang L, Hao M, Wu N, et al. Comprehensive review of tenecteplase for thrombolysis in acute ischemic stroke. J Am Heart Assoc, 2024, 13: e031692
19 Sun L C Y, Li W S, Chen W, et al. Thrombolytic therapy for patients with acute ischemic stroke: systematic review and network meta-analysis of randomized trials. Front Neurol, 2024, 15: 1490476
20 Dong Q, Dong Y, Liu L, et al. The Chinese Stroke Association scientific statement: intravenous thrombolysis in acute ischaemic stroke. Stroke Vasc Neurol, 2017, 2: 147–159
21 Qiao Y, Wang J, Nguyen T, et al. Intravenous thrombolysis with urokinase for acute ischemic stroke. Brain Sci, 2024, 14: 989
22 The National Institute of Neurological Disorders and Stroke rt-PA Stroke Study Group. Tissue plasminogen activator for acute ischemic stroke. N Engl J Med, 1995, 333: 1581–1587
23 Qureshi A I, Siddiqui A M, Kim S H, et al. Reocclusion of recanalized arteries during intra-arterial thrombolysis for acute ischemic stroke. Am J Neuroradiol, 2004, 25: 322–328
24 Mosimann P J, Kaesmacher J, Gautschi D, et al. Predictors of unexpected early reocclusion after successful mechanical thrombectomy in acute ischemic stroke patients. Stroke, 2018, 49: 2643–2651
25 Tao C, Liu T, Cui T, et al. Early Tirofiban infusion after intravenous thrombolysis for stroke. N Engl J Med, 2025, 393: 1191–1201
26 Chen H S, Cui Y, Li X Q, et al. Early antiplatelet treatment for minor stroke following thrombolysis: the EAST trial. Eur Heart J, 2025, 47: 746–756
27 Berkhemer O A, Fransen P S S, Beumer D, et al. A randomized trial of intraarterial treatment for acute ischemic stroke. N Engl J Med, 2015, 372: 11–20

https://www.sciengine.com/doi/10.1360/SSV-2025-0374

28 Campbell B C V, Mitchell P J, Kleinig T J, et al. Endovascular therapy for ischemic stroke with perfusion-imaging selection. N Engl J Med, 2015, 372: 1009–1018

29 Jovin T G, Chamorro A, Cobo E, et al. Thrombectomy within 8 hours after symptom onset in ischemic stroke. N Engl J Med, 2015, 372: 2296–2306

30 Goyal M, Menon B K, van Zwam W H, et al. Endovascular thrombectomy after large-vessel ischaemic stroke: a meta-analysis of individual patient data from five randomised trials. Lancet, 2016, 387: 1723–1731

31 Cagnazzo F, Derraz I, Dargazanli C, et al. Mechanical thrombectomy in patients with acute ischemic stroke and ASPECTS≤6: a meta-analysis. J Neurointerv Surg, 2020, 12: 350–355

32 Brekenfeld C, Gralla J, Zubler C, et al. Mechanische thrombektomie beim akuten schlaganfall. Fortschr Röntgenstr, 2012, 184: 503–512

33 Nogueira R G, Jadhav A P, Haussen D C, et al. Thrombectomy 6 to 24 hours after stroke with a mismatch between deficit and infarct. N Engl J Med, 2018, 378: 11–21

34 Albers G W, Marks M P, Kemp S, et al. Thrombectomy for stroke at 6 to 16 hours with selection by perfusion imaging. N Engl J Med, 2018, 378: 708–718

35 Jovin T G, Li C, Wu L, et al. Trial of thrombectomy 6 to 24 hours after stroke due to basilar-artery occlusion. N Engl J Med, 2022, 387: 1373–1384

36 Tao C, Nogueira R G, Zhu Y, et al. Trial of endovascular treatment of acute basilar-artery occlusion. N Engl J Med, 2022, 387: 1361–1372

37 van Horn N, Kniep H, Leischner H, et al. Predictors of poor clinical outcome despite complete reperfusion in acute ischemic stroke patients. J Neurointerv Surg, 2021, 13: 14–18

38 Heitkamp C, Heitkamp A, Winkelmeier L, et al. Predictors of futile recanalization in ischemic stroke patients with low baseline NIHSS. Int J Stroke, 2024, 19: 1102–1112

39 Chen Y, Zhou S, Yang S, et al. Developing and predicting of early mortality after endovascular thrombectomy in patients with acute ischemic stroke. Front Neurosci, 2022, 16: 1034472

40 Shen H, Killingsworth M C, Bhaskar S M M. Comprehensive meta-analysis of futile recanalization in acute ischemic stroke patients undergoing endovascular thrombectomy: prevalence, factors, and clinical outcomes. Life, 2023, 13: 1965

41 Zhao W, Wu C, Dornbos III D, et al. Multiphase adjuvant neuroprotection: a novel paradigm for improving acute ischemic stroke outcomes. Brain Circ, 2020, 6: 11

42 Zhao M, Wang J, Liu G, et al. Multi-target and multi-phase adjunctive cerebral protection for acute ischemic stroke in the reperfusion era. Biomolecules, 2024, 14: 1181

43 Dammavalam V, Lin S, Nessa S, et al. Neuroprotection during thrombectomy for acute ischemic stroke: a review of future therapies. Int J Mol Sci, 2024, 25: 891

44 Rivet S, Churilov L, Yassi N, et al. Persistent tissue-level hypoperfusion (no-reflow) negates the clinical benefit of successful thrombectomy. Stroke, 2025, 56: 1451–1459

45 Mujanovic A, Ng F, Meinel T R, et al. No-reflow phenomenon in stroke patients: a systematic literature review and meta-analysis of clinical data. Int J Stroke, 2024, 19: 58–67

46 Bai J, Lyden P D. Revisiting cerebral postischemic reperfusion injury: new insights in understanding reperfusion failure, hemorrhage, and edema. Int J Stroke, 2015, 10: 143–152

47 Sanderson T H, Reynolds C A, Kumar R, et al. Molecular mechanisms of ischemia-reperfusion injury in brain: pivotal role of the mitochondrial membrane potential in reactive oxygen species generation. Mol Neurobiol, 2013, 47: 9–23

48 Nie X, Leng X, Miao Z, et al. Clinically ineffective reperfusion after endovascular therapy in acute ischemic stroke. Stroke, 2023, 54: 873–881

49 El Amki M, Glück C, Binder N, et al. Neutrophils obstructing brain capillaries are a major cause of no-reflow in ischemic stroke. Cell Rep, 2020, 33: 108260

50 Zhang Y, Jiang M, Gao Y, et al. “No-reflow” phenomenon in acute ischemic stroke. J Cereb Blood Flow Metab, 2024, 44: 19–37

51 Mondal R, Deb S, Ray N, et al. Advances in collateral neuroimaging for acute ischemic stroke: redefining time and tissue windows in the reperfusion era. J Neuroimag, 2025, 35: e70079

52 Zhang M, Long Z, Liu P, et al. Global burden and risk factors of stroke in young adults, 1990 to 2021: a systematic analysis of the Global Burden of Disease Study 2021. J Am Heart Assoc, 2025, 14: e039387

https://www.sciengine.com/doi/10.1360/SSV-2025-0374

53 Ekker M S, Verhoeven J I, Vaartjes I, et al. Stroke incidence in young adults according to age, subtype, sex, and time trends. Neurology, 2019, 92: e2444

54 Feigin V L, Abate M D, Abate Y H, et al. Global, regional, and national burden of stroke and its risk factors, 1990–2021: a systematic analysis for the Global Burden of Disease Study 2021. Lancet Neurol, 2024, 23: 973–1003

55 He M, Zhang S, Liu X, et al. Global, regional, and national epidemiology of ischemic stroke in young adults, 1990–2021. J Neurol, 2025, 272: 354

56 Ma Z, He W, Zhou Y, et al. Global burden of stroke in adolescents and young adults (aged 15–39 years) from 1990 to 2019: a comprehensive trend analysis based on the global burden of disease study 2019. BMC Public Health, 2024, 24: 2042

57 Ohya Y, Matsuo R, Sato N, et al. Causes of ischemic stroke in young adults versus non-young adults: a multicenter hospital-based observational study. PLoS One, 2022, 17: e0268481

58 Huang L, Wang Y, Wang Y, et al. Etiologies and risk factors by sex and age in young adult patients with ischemic stroke. Curr Neurovasc Res, 2025, 21: 574–583

59 Tang M, Yao M, Zhu Y, et al. Sex differences of ischemic stroke in young adults—a single-center Chinese cohort study. J Stroke Cerebrovasc Dis, 2020, 29: 105087

60 Osteraas N D. Sex-based difference in selected stroke etiologies: cerebral dural sinus venous thrombosis, reversible cerebral vasoconstriction syndrome, dissection, migraine, pregnancy/puerperium/OC use. J Stroke Cerebrovasc Dis, 2024, 33: 107753

61 Linstra K M, van Os H J A, Ruigrok Y M, et al. Sex differences in risk profile, stroke cause and outcome in ischemic stroke patients with and without migraine. Front Neurosci, 2021, 15: 740639

62 Ioannidis S G, Mitsias P D. Patent foramen ovale in cryptogenic ischemic stroke: direct cause, risk factor, or incidental finding? Front Neurol, 2020, 11: 567

63 Kent D M, Wang A Y. Patent foramen ovale and stroke: a review. JAMA, 2025, 334: 1463

64 Handke M, Harloff A, Olschewski M, et al. Patent foramen ovale and cryptogenic stroke in older patients. N Engl J Med, 2007, 357: 2262–2268

65 von Sarnowski B, Putaala J, Grittner U, et al. Lifestyle risk factors for ischemic stroke and transient ischemic attack in young adults in the Stroke in Young Fabry Patients Study. Stroke, 2013, 44: 119–125

66 Mastrangelo M, Ricciardi G, Giordo L, et al. Stroke and stroke-like episodes in inborn errors of metabolism: pathophysiological and clinical implications. Mol Genet Metab, 2022, 135: 3–14

67 Silliman S. Mendelian and mitochondrial disorders associated with stroke. J Stroke Cerebrovasc Dis, 2002, 11: 252–264

68 Liu L Y, Aimaiti X, Zheng Y Y, et al. Epidemic trends of dyslipidemia in young adults: a real-world study including more than 20,000 samples. Lipids Health Dis, 2023, 22: 108

69 Ma S, Yang L, Zhao M, et al. Trends in hypertension prevalence, awareness, treatment and control rates among Chinese adults, 1991–2015. J Hypertens, 2021, 39: 740–748

70 Wang L, Peng W, Zhao Z, et al. Prevalence and treatment of diabetes in China, 2013–2018. JAMA, 2021, 326: 2498

71 Siegel C, Marchandot B, Matsushita K, et al. The effect of transoesophageal echocardiography on treatment change in a high-volume stroke unit. J Clin Med, 2021, 10: 805

72 Ahmed M K, Kamal H, Weiss J L, et al. Transesophageal echocardiogram in the evaluation of acute ischemic stroke of young adults. Brain Circ, 2021, 7: 85–91

73 Boot E, Ekker M S, Putaala J, et al. Ischaemic stroke in young adults: a global perspective. J Neurol Neurosurg Psychiatry, 2020, 91: 411–417

74 Ge J J, Xing Y Q, Chen H X, et al. Analysis of young ischemic stroke patients in northeast China. Ann Transl Med, 2020, 8: 3

75 Jacob M A, Ekker M S, Allach Y, et al. Global differences in risk factors, etiology, and outcome of ischemic stroke in young adults—a worldwide meta-analysis. Neurology, 2022, 98: 86

76 van Dongen M M E, Aarnio K, Martinez-Majander N, et al. Use of antihypertensive medication after ischemic stroke in young adults and its association with long-term outcome. Ann Med, 2019, 51: 68–77

77 Bushnell C D, Zimmer L O, Pan W, et al. Persistence with stroke prevention medications 3 months after hospitalization. Arch Neurol, 2010, 67: 1456

78 Chandler C, Clarissa C, Putri A F, et al. Young adults rehabilitation experiences and needs following stroke (YARNS): a scoping review of the rehabilitation care experiences and outcomes of young adults post-stroke. PLoS One, 2025, 20: e0279523

https://www.sciengine.com/doi/10.1360/SSV-2025-0374

79 Ignacio K H D, Muir R T, Diestro J D B, et al. Prevalence of depression and anxiety symptoms after stroke in young adults: a systematic review and meta-analysis. J Stroke Cerebrovasc Dis, 2024, 33: 107732
80 Chau J P C, Lo S H S, Zhao J, et al. Factors associated with post-stroke depression in Chinese stroke survivors. J Stroke Cerebrovasc Dis, 2021, 30: 106076
81 Wang X, Shang S, Yang H, et al. Associations of psychological distress with positive psychological variables and activities of daily living among stroke patients: a cross-sectional study. BMC Psychiatry, 2019, 19: 381
82 Tu W J, Wang L D, Yan F, et al. China stroke surveillance report 2021. Mil Med Res, 2023, 10: 33
83 Liu J L, Fu J F, Wang C L, et al. The construction of comprehensive stroke prevention and control system requires attention to the precise policies of young stroke (in Chinese). Chin J Prev Med, 2022, 56: 245–249 [刘竞丽, 傅金凤, 王辞岚, 等. 卒中全面防控体系的构建需关注青年卒中的精准施策. 中华预防医学杂志, 2022, 56: 245–249]
84 Jiang B. Current snapshots on stroke prevention and control and more proactive national strategies against it in China. J Cent Nerv Syst Dis, 2025, 17: 11795735251337605
85 Chao B H, Yan F, Hua Y, et al. Stroke prevention and control system in China: CSPPC-Stroke program. Int J Stroke, 2021, 16: 265–272
86 Sui Y, Luo J, Dong C, et al. Implementation of regional Acute Stroke Care Map increases thrombolysis rates for acute ischaemic stroke in Chinese urban area in only 3 months. Stroke Vasc Neurol, 2021, 6: 87–94
87 Wen R, Wang M, Bian W, et al. Implementation of regional Acute Stroke Care Map increases thrombolysis rates in urban areas of China: an interrupted time series analysis. Int J Qual Health Care, 2025, 37: mzaf022
88 Wu S, Wu B, Liu M, et al. Stroke in China: advances and challenges in epidemiology, prevention, and management. Lancet Neurol, 2019, 18: 394–405
89 Chao B H, Tu W J, Wang L D. Initial establishment of a stroke management model in China: 10 years (2011–2020) of Stroke Prevention Project Committee, National Health Commission. Chin Med J, 2021, 134: 2418–2420
90 Stroke Prevention Project, National Health Commission, Ji X M. Brief report on stroke prevention and treatment in China, 2024 (in Chinese). J Cap Med Univ, 2025, 46: 947–960 [国家卫生健康委加强脑卒中防治工作减少百万新发残疾工程专家委员会, 吉训明. 《2024年中国脑卒中防治报告》概要. 首都医科大学学报, 2025, 46: 947–960]
91 Adeniji O, Olowoyo P, Akinyemi R, et al. Advances in primordial, primary, and secondary prevention of stroke in diverse populations. Stroke, 2024, 55: 2359–2365
92 Govori V, Budincevic H, Morovic S, et al. Updated perspectives on lifestyle interventions as secondary stroke prevention measures: a narrative review. Medicina, 2024, 60: 504
93 Leng X, Hurford R, Feng X, et al. Intracranial arterial stenosis in Caucasian versus Chinese patients with TIA and minor stroke: two contemporaneous cohorts and a systematic review. J Neurol Neurosurg Psychiatry, 2021, 92: 590–597
94 Hurford R, Rothwell P M. Prevalence, prognosis, and treatment of atherosclerotic intracranial stenosis in Caucasians. Int J Stroke, 2021, 16: 248–264
95 Song J Y, Kwon S U. Intracranial atherosclerotic stenosis. Cerebrovasc Dis Extra, 2025, 15: 62–67
96 Tan Y, Pan Y, Liu L, et al. One-year outcomes and secondary prevention in patients after acute minor stroke: results from the China National Stroke Registry. Neurol Res, 2017, 39: 484–491
97 Mao C, Li M. Stroke recurrence as a challenge for countries. JAMA Netw Open, 2022, 5: e2219698
98 Joubert J, Davis S M, Donnan G A, et al. ICARUSS: an effective model for risk factor management in stroke survivors. Int J Stroke, 2020, 15: 438–453
99 Yan L L, Gong E, Gu W, et al. Effectiveness of a primary care-based integrated mobile health intervention for stroke management in rural China (SINEMA): a cluster-randomized controlled trial. PLoS Med, 2021, 18: e1003582

https://www.sciengine.com/doi/10.1360/SSV-2025-0374

Stroke prevention and treatment: current status, challenges, and future directions

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Stroke is the leading cause of adult mortality and disability in China, imposing a heavy socioeconomic burden and representing a key disease for prevention and control under the Healthy China 2030 strategy. Over the past decade, the management of stroke in China has improved markedly, with the widespread use of reperfusion therapies including thrombolysis and thrombectomy, optimized emergency care pathways, and a well-established stroke center system, leading to extended therapeutic time windows and higher vascular recanalization rates. However, several critical challenges remain: the benefits of recanalization have not been fully translated into better neurological recovery, resulting in unfavorable outcomes in many patients; the incidence of young-onset stroke continues to rise, posing a threat to the social labor force; and weaknesses persist in the prevention and control system, such as fragmented prevention, inadequate risk factor management, and insufficient capacity at the primary care level. This paper reviews the current status, challenges, and future directions of stroke prevention and treatment in China, focusing on three aspects: the bottlenecks in reperfusion therapy for acute ischemic stroke, the prevention and control of young-onset stroke, and the establishment of a stroke prevention system with Chinese characteristics, aiming to provide evidence for improving the overall prevention and control of stroke.

stroke, reperfusion therapy, young-onset stroke, stroke prevention and treatment system

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